ILLINOIS
STATE GEOLOGICAL SURVEY.

BULLETIN No. 13.

The Mississippi Valley Between Savanna and Davenport.

BY

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Urbana
University of Illinois
1909

SPRINGFIELD, ILL.,
ILLINOIS STATE JOURNAL CO., STATE PRINTERS
1910

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ERRATA

Since proof of this report was read in the absence of the author from the office, a number of errors were unfortunately overlooked The following are of importance.

Page XI, paragraph 3, line 4, for "12, 8 and 16." read "7 and 9."
XI, paragraph 3, line 8, for "7," read "9."
8, foot note 3, for "Am. Rept.", read "Ann. Rept., Pt. 2."
9, column 1, for "156," read "106."
20, line 10, for "p. 10," read "p. 12."
24, Pl. 5A, for "Pl. 2B," read "Pl. 4B."
32, Pl. 9, after "Wisconsin," insert "Iowa."
36, paragraph 3, line 9, for "Pl. 1," read "Pl. 1 and 2."
37, line 7 from bottom, omit "and 13A."
48, Pl. 13A, for "10," read "12."
62, line 13 from bottom, for "distant," read "distinct."
71, line 13 from bottom, for "(p.........)," read "(p. 36)."
75, line 9, after "17," insert "C."
78, Pl. 19A, for "a dune," read "dune sand."

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LETTER OF TRANSMITTAL.

State Geological Survey,
University of Illinois,
Urbana, December 1, 1909.

Governor C. S. Deneen, Chairman, and Members of the Geological Commission:

Gentlemen—I submit herewith a report on the Mississippi Valley between Savanna and Davenport by J. Ernest Carman, and recommend that it be published as Bulletin 13, of the Survey. This was planned by Doctor Bain as an addition to our "Eductional Bulletins," and was prepared under the direction of Professor R. D. Salisbury, Consulting Geologist of the Survey. Since the area is traversed by the Mississippi so as to include nearly equal parts of Illinois and Iowa, the field study was carried on in coöperation with Professor Calvin, State Geologist of Iowa.

The large population of this district is due to the advantages of location on the river and to the fertility of adjoining farm lands. It may be assumed, therefore, that intelligent citizens as well as students in the schools will be glad to gain a better understanding of their natural environment. This indeed is the purpose of the "Educational Bulletins." This region is situated in the path of three distinct glacial invasions, and, therefore, has a wealth of interesting phenomena deserving interpretation. The drainage changes of the Mississippi river, due to ice invasions, is especially interesting.

The Survey is greatly indebted to Professor Salisbury and to Mr. Carman for the attractiveness of this bulletin. Special acknowledgment should be made to Professor Calvin for advice in the work, and for the use of the illustrations on Plates 1, 2, 8 and 16. Thanks is similarly due to the publishers of Chamberlin and Salisbury's Geology for the use of Figures 7, 8 and 10. The United States Geological Survey furnished the topographic base for Plates 1 and 2, and the illustrations for Plate 7 and Figures 12 and 14. Thanks is due to Mr. A. C. Trowbridge for taking many of the photographs, and to Professor J. A. Udden for the use of unpublished field notes.

Very respectfully,

Frank W. DeWolf,
Acting Director.

THE MISSISSIPPI VALLEY BETWEEN SAVANNA AND DAVENPORT.

CHAPTER I.—INTRODUCTION.

AREA COVERED.

The area discussed in this bulletin is partly in Illinois, and partly in Iowa. It lies along the Mississippi river from Savanna on the north, to the mouth of Rock river on the south, a distance of about sixty miles.

FIG. 1. Outline map of a part of eastern Iowa and western Illinois, showing relation of the region considered in this Bulletin to the states and counties and to the topographic sheets of the U. S. Geological Survey. The region here considered is surrounded by the broken line.

It includes parts of Carroll, Whiteside, Rock Island and Henry counties in Illinois, and parts of Jackson, Clinton and Scott counties in Iowa. The relation of the region studied to the states and counties, and to the topographic sheets of the U. S. Geological Survey is shown in Figure 1. As will be seen from the figure, most of the region is included within the area covered by the Cordova map of the U. S. Geological Survey.[1] The region here considered extends northward into the Savanna quadrangle, includes the southeast corner of the Rock Island quadrangle, and extends southward to a point just below the mouth of Rock river. The area studied, however, can hardly be said to have hard and fast boundaries.

The stronger physiographic features of the region are centered along the Mississippi valley, and the work done in the preparation of this bulletin was extended back from the main river, only far enough to cover the lower courses of the larger tributaries.

PURPOSE OF THIS BULLETIN.

It is the main purpose of this bulletin to set forth in simple terms the development of the existing topography; and the field work done in the preparation of this report had this purpose in mind. The geology of the region is discussed only in so far as it helps to explain the present surface. More detailed discussion of the rock strata may be found in the Iowa and Illinois reports, and in various independent papers. Considerable work has been done in this region by various surveys and individuals. The Iowa county reports deal with the Iowa side.[2] Meagre notes on the Illinois counties are found in the old Illinois Survey reports.[3] In Monograph XXXVIII of the U. S. Geological Survey, Mr. Frank Leverett treats the region as a part of the much larger area considered in his report. In the work done in the preparation of this bulletin, existing maps and reports were used, and the field work was in some measure a verification of former conclusions; but it was also a search for new data along particular lines. In the preparation of this report existing publications have been freely drawn upon.

GENERAL CHARACTERISTICS OF THE REGION.

Topographic.—The region is an upland plain, diversified by a few large valleys with wide flats, and by many small valleys with narrow flats, or with none. The upland has a somewhat uneven surface at an elevation of 700 to 900 feet above the sea. The most pronounced topographic feature of the region is the great Mississippi valley, which extends in a general north-south direction across the area, 100 to 200 feet deep, and for most of its course 3 to 6 miles wide. Tributary to it are other great valleys such as that of the Wapsipinicon river from

1 The topographic maps of the U. S. Geological Survey are called *sheets* or *quadrangles*, a quadrangle being the rectangular area mapped on one topographic sheet. The topographic maps are sold by the U. S. Geological Survey at 5 cents a copy. Correspondence should be addressed to, *"The Director," U. S. Geological Survey, Washington, D. C.*

2 Iowa Geological Survey Reports: Jackson County Savage; Vol. XVI, 1905, pp. 563-648. Clinton County, Udden; Vol. XV, 1904, pp. 371-431. Scott County, Norton; Vol. IX, 1898, pp. 391-519.

3 Geological Survey of Illinois, Vol. V, 1873: Carroll County, Chap. IV, pp. 75-81. Whiteside County, Chap. IX, pp. 140-166. Rock Island County, Chap. XIII, pp. 217-234. Henry County, Chap. XI, pp. 185-201.

the west, and that of Rock river from the east, together with several other valleys not now occupied by streams. Besides these larger valleys, many smaller ones join the Mississippi from either side. The most important of these from the east are the valleys of Plum river and Johnson, Otter and Spring creeks, and from the west those of Elk river and Mill, Spencer and Duck creeks. Still smaller valleys and ravines join these larger ones, but their relations to one another and to the larger valleys, show that the Mississippi river has been the controlling factor in the development of the topography of the region.

The larger valleys completely surround certain upland areas. East of the Mississippi river, southeast of Clinton, a highland area is surrounded by the Mississippi valley and the Meredosia and Cattail channels (Pl. I.) This upland area is triangular in shape, each side being about 10 miles long. It will be referred to as the *Garden Plain upland.*

East of the narrow part of the Mississippi valley, between Cordova and Hampton (known as *the Narrows*), is another upland area surrounded by valleys. It is bounded on the north by the *Cordova Flats,* and on the east and south by the Rock River valley and *Pleasant valley,* an abandoned water course leading west from Rock river at Barstow, past East Moline, to the Mississippi (Pl. I.) This upland will be called the *Coe upland* from the township which includes most of the area. Topographically, the Coe upland belongs with the upland of Scott county, Iowa, of which it appears to be an eastward extension, cut off by the narrow valley of the Mississippi.

The small upland area lying south of Moline and Rock Island, and completely surrounded by the valleys of the Mississippi and Rock rivers, and Pleasant valley, will be referred to, as the *Moline upland.* The lesser island-like elevations at Fulton, Clinton, Albany and Cordova, may bear the names of those places.

The larger valleys are as a rule about 200 feet below the adjacent uplands. The highest elevation of the region is near its northern boundary, and is more than 960 feet above the sea. The Mississippi river below Leclair is less than 500 feet above the sea. This gives a maximum relief of more than 460 feet.

Geologic.—The upland of the region is very generally covered with a fine grained yellow loam, known to geologists as *loess.* Below the

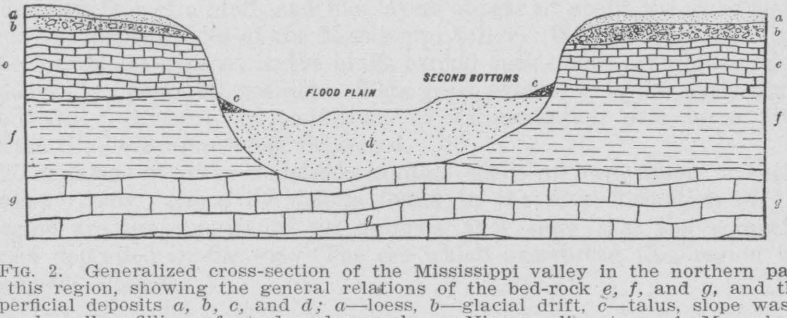


FIG. 2. Generalized cross-section of the Mississippi valley in the northern part of this region, showing the general relations of the bed-rock *e, f,* and *g,* and the superficial deposits *a, b, c,* and *d*; *a*—loess, *b*—glacial drift, *c*—talus, slope wash, etc., *d*—valley filling of sand and gravel; *e*—Niagara limestone, *f*—Maquoketa shale, and *g*—Galena-Trenton limestone.

loess there is, over much of the region, a variable thickness of yellowish or bluish clay, with which are mixed variable quantities of sand, gravel, and bowlders. This is known as *drift*. In the valleys the surface material is sandy or loamy, and is often underlain by thick deposits of sand and gravel.

Beneath these loose (*superficial*) deposits is the *bed-rock*, which consists of layers of different kinds of rock, the beds of which are in a nearly horizontal position. Exposures of rock (*outcrops*) are frequent along the bluffs of the great valleys, and in the slopes of some of the smaller ones. The general relations of the bed-rock and the superficial deposits are shown in Fig. 2, which is a generalized section across the Mississippi valley.

CHAPTER II.

THE BED-ROCK FORMATIONS.

General Statement.

ORIGIN OF BED-ROCK.

It has been stated that the rock strata underlying this region are made up of different kinds of rock. These rocks include limestones, shales and sandstones. Limestone appears at the surface over a greater area than the other kinds of rock, and shale appears at the surface more commonly than sandstone, which is seen in a few places only. If we study the rocks, we find (1) that the sandstone is made up of grains of sand cemented together by a mineral cement; (2) that the shale is made up of particles of mud similarly cemented; and (3) that the limestone is made up of calcareous materials, such as shells, corals and limey oozes, made by the grinding and breaking of shells, corals, etc. The original deposits from which the rocks were formed were, therefore, sands, muds, and calcareous material. These are just the sorts of material that are now being deposited in the shallow waters about the borders of lakes and oceans. From these facts we infer that this area was once beneath water, and that sediments from neighboring lands were laid down over it in standing water. Cementation by mineral matter which was once in solution in water, bound the particles of sediment together, making the present bed-rock. Such bed-rocks formed by deposition and cementation of sediments, are known as *sedimentary rocks.*

Certain layers of rock may often be traced for considerable distance along the face of a bluff, and like layers appear at about the same elevation on opposite sides of the Mississippi valley. Well borings show that the formations exposed in the bluffs extend back under the upland in an essentially horizontal position. This great extent of layers horizontally indicates uniformity of conditions of sedimentation over large areas while the beds were being deposited.

The layers of rocks sometimes contain shells or impressions of shells, called *fossils.* Since the fossils found in the rock formation of this region are the remains of sea animals, they show that the sediments were deposited in the sea. The sea which overspread this region was probably shallow.

THE GEOLOGIC COLUMN.

The *geologic column* is the name given to the full succession of rock formations, wherever found. The complete geologic column is not found in any one region.

The several formations of rock which appear at the surface within this region belong to a few of the systems of this column. In the following table the geologic column is given, the oldest system being at the bottom. The names of the systems represented at the surface in this region, are in italic.

GROUP.	SYSTEM.	
Cenozoic	*Quaternary*	
	Tertiary	
Mesozoic	Cretaceous	
	Comanchean (Lower Cretaceous)	
	Jurassic	
	Triassic	
Paleozoic	Permian	
	Pennsylvanian	
	Mississippian (Sub-Carboniferous)	
	Devonian	
	Silurian	
	Ordovician	
	Cambrian	
Proterozoic	Keweenawan	
	Animikean	
	Huronian	Upper
		Lower
Archeozoic	Archean	

DESCRIPTION OF THE BED-ROCK FORMATIONS.

The thickness of the sedimentary formations exposed and penetrated by wells in this region, is about 1,500 feet. This great thickness of sedimentary rocks shows that the conditions of sedimentation must have existed for a long time over this region. Moreover the series is not a continuous one. There were long intervals when the region did not receive sediments, but when those which had been deposited were being removed by erosion.

The following table, compiled from the county reports of the Iowa Geological Survey, shows the general relations of the rocks exposed in this region:

Group.	System.	Series.	Stage.	Sub-Stage.
Cenozoic.	Quaternary.	Recent.	Alluvial.	
		Pleistocene.	Wisconsin. (Valley filling)	
			Iowan.	
			Illinoian.	
			Kansan.	
			Pre-Kansan?	
Paleozoic.	Pennsylvanian.		Des Moines.	
	Devonian.	Middle Devonian.	Cedar Valley.	Dielasma beds.
				Spirifer Parryanus beds.
			Wapsipinicon.	Upper Davenport.
				Lower Davenport.
				Independence.
				Otis.
	Silurian.	Middle Silurian. (Niagran.)	Gower.	Anamosa (and) Leclaire.
			Hopkinton. (Delaware.)	
	Ordovician.	Upper Ordovician. (Cincinnatian.)	Maquoketa.	

THE CAMBRIAN SYSTEM.

No rocks of the Cambrian system appear at the surface within this region, but they have been penetrated by deep wells. They consist largely of sandstone; but thick beds of limestone, some shale, and various gradations between these sorts of rock occur. The divisions and nature of the material may be seen from the table of artesian well records.

No wells have reached the bottom of the Cambrian system, but it has been penetrated more than 600 feet. The sandstones of this system yield most of the water for the artesian wells of this region.

THE ORDOVICIAN SYSTEM.

Unexposed Formations Penetrated by Wells.—The larger part of the Ordovician system does not appear at the surface, and is known only

Table of artesian well records showing thickness of

<table>
<tr><th rowspan="2">System.</th><th rowspan="2">FORMATION.</th><th rowspan="2">Sabula town well.[1]</th><th colspan="3">CLINTON.</th></tr>
<tr><th>C. & N. W. Ry. well.[1]</th><th>Dewitt park well.[1]</th><th>First water-works well.[1]</th></tr>
<tr><td rowspan="4">Ordovician.</td><td>Maquoketa shale</td><td></td><td>295</td><td>160[3]</td><td>180</td></tr>
<tr><td>Galena-Trenton limestone</td><td>212</td><td>275</td><td>430[3]</td><td>325</td></tr>
<tr><td>St. Peter's sandstone</td><td>75</td><td>60</td><td>40</td><td>100</td></tr>
<tr><td>Oneota limestone, (lower magnesian)</td><td>325</td><td>380</td><td rowspan="2">Limestone and sandstone 800</td><td>300</td></tr>
<tr><td>Cambrian.</td><td>Jordan sandstone.
St. Lawrence limestone.
Basal sandstones and shales.</td><td></td><td></td><td>Sandstone 125
Limestone 250
Basal sandstone 300</td></tr>
</table>

[1] Norton, Iowa Geol. Surv., Vol. VI, pp. 245 and 261.
[2] Udden, Iowa Geol. Surv., Vol. XV, p. 384.
[3] Udden, U. S. Geol. Surv., 17th Am. Rept., pp. 841-845.

formations penetrated below the Silurian system,

Waterworks well 1902.[2]	Davenport Glucose works well.[3]	Rock Island, Mitchell and Lynde bldg.[3]	Moline Prospect park well.[3]	East Moline E. Moline Improvement Co.[3]	Milan town well.[3]
227	225	182	235	265	215
318	334	443	330	300	325
156	72	145	120†	220	195
308					
Sandstone 25 Limestone 155 Shale 93 Sandstone 252 Shale 55	Limestone 788 Shale 40 Sandy limestone 20 Sandy rock 160 Shale 51	Limestone 811 Sandstone 30 Limestone 35 Sandstone 130 Sandy limestone and shale 75 Sandstone 97			

from well records. In ascending order, the unexposed formations known by borings are *Oneota, (Lower Magnesian), limestone, St. Peters sandstone, and Galena-Trenton limestone,* all of which lie below the Maquoketa shale. The limestone formations are each about 300 feet thick, and are separated by about 100 feet of shale and sandstone (See table). The St. Peters sandstone is a water bearing formation of considerable importance, but secondary to the Cambrian sandstones.

The Exposed Formation—(The Maquoketa Shale.)

The lowest and therefore the oldest formation exposed at the surface is the Maquoketa shale, the highest member of the *Ordovician system.*[1] (p. 7).

The general distribution of the Maquoketa shale and the other formation described in this chapter is shown on the geologic maps of Iowa and Illinois. The county reports of the Iowa Geological Survey (See footnote p. 2) include geologic maps of the several counties; and "A Provisional Geologic Map of Illinois," was published as Bulletin No. 6, of the Illinois State Geological Survey.

Extent and Outcrops.—The Maquoketa shale comes to the surface in the base of the Mississippi bluffs on the Iowa side of the river, just north of Lyons, and from there continues northward beyond the area under consideration. It extends almost a mile up the creek valley in Sec. 18, Spring Valley township, Clinton county, and several miles up Elk River valley. North of Lyons the upper surface of the shale is 40 to 50 feet above the river, and at an elevation of about 620 feet above the sea.

On the Illinois side of the river the shale is first seen in the point of the bluff just to the north of Johnson creek. It extends 40 to 50 feet above the road, up to an elevation of about 675 feet. The outcrop continues northward along the lower part of the bluff to Sec. 32, Mt. Carroll township. From this point to Plum river, the shale was not seen, but it appears again in the bluffs north of Plum river, and at Savanna.

In the northeast part of York township and the southern part of Mt. Carroll township, Carroll county, Illinois, in the region around Argo and southeast of Hickory Grove, the Maquoketa shale is the uppermost bed-rock, although in the Mississippi valley bluffs to the west, limestone, comes well down toward the base of the bluff and is the only rock exposed. These upland exposures occur at various elevations up to 750 to 775 feet.

North of Clinton the broad valley of the Mississippi is probably underlain by this formation; or if the shale has all been cut away, the thick alluvial deposit of the valley rests upon the Galena-Trenton limestone.

Structure.—On the Iowa side of the river, the top of the shale has a nearly constant elevation from Lyons north to Jackson county. West of Sabula, the bluff cuts across a low east-west anticline (Fig. 3), and the upper contact of the shale has an elevation of 80 to 90 feet above the river. It dips in either direction and soon has its usual elevation

1 Recently the question has been raised whether this formation should not be made the base of the Silurian system, rather than the top of the Ordovician.

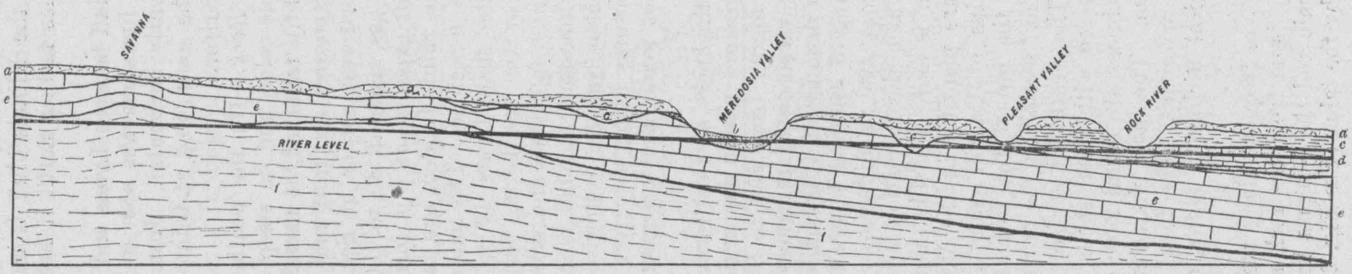


FIG. 3. Generalized section through the region from north to south, showing the southward dip of the formations, the anticline at Savanna, and the succession of surface outcrops. *a*—drift, *b*—valley filling of sand and gravel, *c*—Coal Measures, *d*—Devonian limestone, *e*—Niagara limestone, and *f*—Maquoketa shale.

of 40 to 50 feet above the river. At Savanna the surface of the shale on the anticline in the Illinois bluff is more than 100 feet above the river, while two miles farther north it has declined to within 25 feet of the river.

Along the river bluff between Lyons and Elk river, the contact of the shale and overlying limestone was seen in several places. The contact is sharp and apparently horizontal. Just north of Lyons the contact dips (declines) to the south, and at Clinton is more than 100 feet below the level of the river.

Character of the Rock.—On the weathered surface, the Maquoketa shale has a light blue color, and on steep slopes where it has slumped down and been slightly reworked, it usually appears as a sticky, light blue clay. Fresh exposures are rare, and found only in recent excavations. In the northwest corner of Sec. 27, Mt. Carroll township, the C. B. & Q. Ry. has made an 80 to 100 foot cut through a divide, affording an excellent exposure of this formation. As seen in the cut, the shale is dark blue, thinly bedded, and interstratified with thin layers of compact blue-gray limestone. The limestone layers are two to three inches thick, and the shale layers 12 to 24 inches. The limestone layers are released by the weathering away of the shale, and break up into thin slabs which fall down and strew the surface below. At the top of the cut, the limestone becomes more abundant, and the formation passes into a slabby, impure, yellowish limestone, which has many fossils. In the exposures along the river bluffs, the limestone layers and capping were not found, the formation consisting more uniformly of shale.

Thickness.—The thickness of this formation cannot be determined from its surface exposures within the region, but artesian wells show for it a thickness ranging from 150 to 300 feet. The Clinton wells show a considerable variation of thickness of the formation although they are all within a distance of a half mile. The difference is perhaps due to the interpreting of different layers as the top and bottom of the formation. There may also be differences in thickness, due to an irregular base upon which the formation rests, or to an irregular upper surface. The former is more probable than the latter.

Fossils.—Fossils are plentiful in the Maquoketa shale in York and Mt. Carroll townships of Carroll county, Illinois, especially in the slabby limestone at the top of the formation. The best locality for fossils is the "Big Cut" section in the northwest corner of Sec. 27, Mt. Carroll township. The weathered surface of the limestone blocks are often completely covered with fossil shells, but it is difficult to detach them. The best specimens are found loose on the slopes, having weathered out of the stone. The most characteristic fossils of this horizon are brachiopods and bryozoans. The fossil *fauna* (all the fossils taken together) is the typical Richmond fauna, of the Upper Ordovician as commonly classified.

Springs.—Springs are frequent along the bluffs of the northern part of the region. They issue from the rock at or just above the contact of the Maquoketa shale and the Niagara limestone; but as this contact is usually concealed by the talus (See Fig. 2), the water often percolates downward through the loose deposit and does not reach the surface. Where the talus is absent, springs are much more numerous. They appear well above the base of the bluff, and are useful as a source of water supply.

The principles illustrated here are the general ones for springs. The Niagara and overlying deposits are pervious, and allow the water to percolate through them. But its downward course is stopped by the relatively impervious Maquoketa shale, (*c* Fig. 4), and it then moves horizontally along the contact until it finds a point of issue in the valley wall, as at *s*.

THE SILURIAN SYSTEM—THE NIAGARA LIMESTONE.

General Characteristics and Thickness.—The Niagara formation is a yellow-to-gray magnesian limestone. Its surface weathers into pockets and cavities, and the rock as a whole is rather porous. The beds range from thin layers in some portions of the formation, to those 8 to 10 feet in thickness in others. A complete section of the Niagara occurs

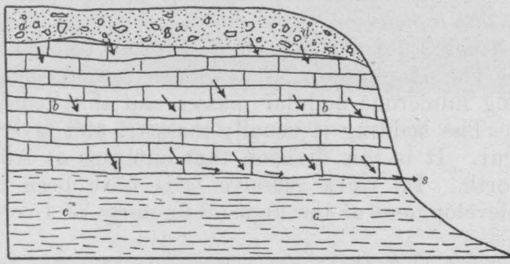


FIG. 4. Diagram to show the origin of springs issuing from the valley sides. *a*—drift, loess, etc., and *b*—Niagara limestone, both of which are relatively pervious; *c*—Maquoketa shale, which is relatively impervious. The arrows show the direction of flow of percolating water. The spring issues at *s*.

within the region, the base overlying the Maquoketa shale at the north, and the top passing under the Devonian limestone at the south. Outcrops of the Niagara, however, are by no means continuous, and a measurement of its thickness from surface exposures is impossible. At Clinton, the wells pass through 120 to 180 feet feet of limestone before reaching the shale, but the upper part of the formation has been eroded away at this place. Professor Udden, after a study of the artesian well records of Davenport, Rock Island and Moline, where the formation does not appear at the surface, gives the average thickness as 340 feet.[1]

Extent and Outcrops.—The Niagara limestone has, by far, the largest extent at the surface, of any of the rock formations of this region. The southern border of the Niagara area on the Iowa side, passes in a general east-southeast direction across the south central part of Scott county, reaching the river in the region of Pigeon creek, south of Pleasant valley. On the Illinois side, the boundary continues in a general easterly direction from Watertown, crossing the Rock river near

[1] Udden. U. S. Geol. Surv., Seventeenth Ann. Rept., Pt. II, p. 834.

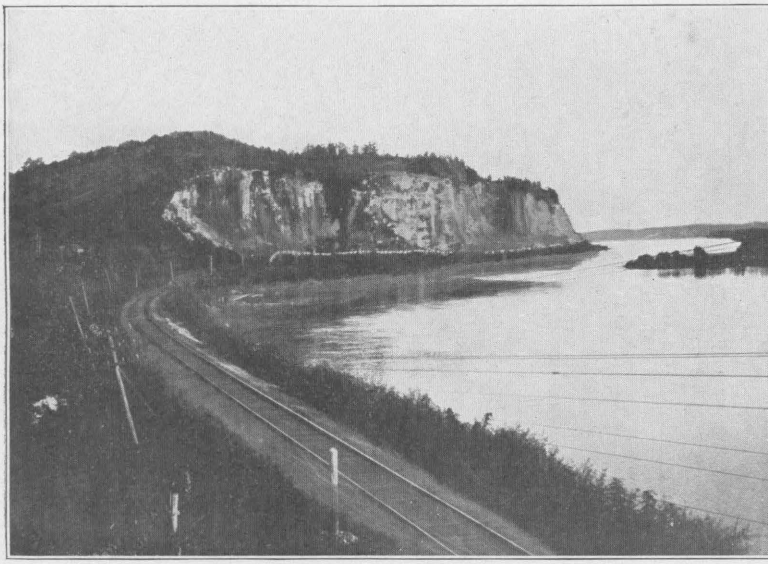
Joslyn. North of this line the Niagara is the uppermost rock below the drift of the upland, except for a number of isolated patches of younger rock, and the areas of Maquoketa shale, previously noted. It extends off to the north, east and west, beyond the limits of this region.

The formation outcrops in the bluffs of the river from the north end of the region to the villages of Pleasant Valley and Watertown. North of Lyons, the bluffs rise 100 to 150 feet above the river, and usually expose a wall of 50 to 75 feet of Niagara limestone above a talus covered slope which conceals the Maquoketa shale at the base (Fig. 2). Similar exposures are found in the bluffs of the Illinois side between Otter creek and a point west of Hickory grove, and again north of Savanna, where cliffs expose 100 to 125 feet of limestone in an almost vertical wall (Pl. 3, A.) Other good exposures are found in the quarries along Bluff street in the west part of Clinton, along the west and north sides of the Fulton hill, at Albany, along the south bluff of the Wapsipinicon valley, at the northeast corner of the Coe upland overlooking the Meredosia bottoms, in the Narrows between Princeton and Watertown, in the quarries at Leclaire and Port Byron, in the lower course of Spencer creek, and at many other places throughout the region.

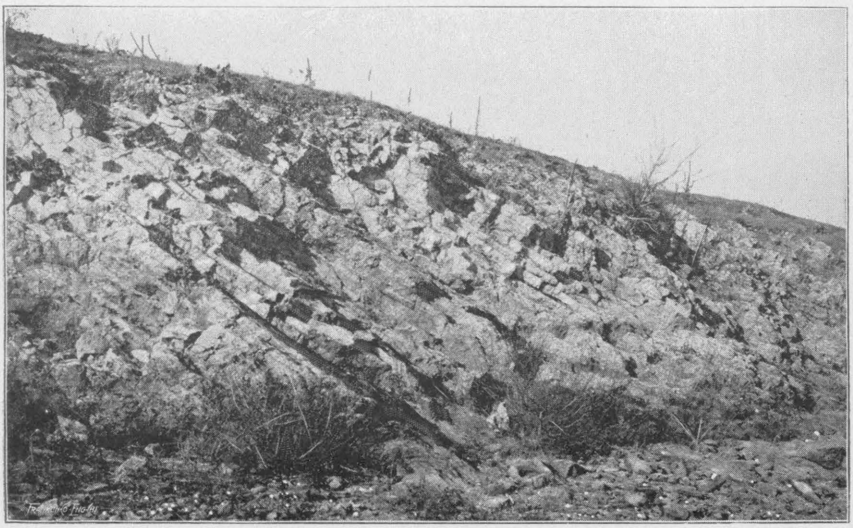
Divisions of the Formation.—The Iowa geologists recognize two divisions of the Niagara formation, the *Hopkinton* below and the *Gower* above (p. 7). The Hopkington is a yellow, porous, magnesian limestone, containing numerous nodular masses and thin bands of chert in its lower part. The bedding is usually massive, and layers 4 to 6 feet thick often occur. It is this division that outcrops at Albany, Clinton and farther north. Its thick massive beds have been an important feature in the development of the high bluffs north of Lyons and Fulton (Pl. 3, A.)

In the Hopkinton beds there are a few characteristic fossils. North of Savanna in the layers making up the base of the scenic feature known as the "Twin Sisters," a very characteristic shell is so abundant as to make up a considerable part of the rock. The shell is oblong, pointed at one end, and compressed in one direction. It is known as *Pentamerus oblongus,* and the beds in which it occurs have been called the *Pentamerus beds.* Other characteristic fossils of this locality are a honey-comb coral, *Favosites Niagarensis,* a chain coral, *Halysites catenulata,* and a cup coral. These fossils and others may be found at a number of other localities, as in the west part of Clinton and at Albany, but in general the formation does not contain many fossils.

The Gower limestone occurs at the surface in the southern part of the Niagara area. It also is a magnesian limestone, less porous than the Hopkinton, and of a blue-gray color. The Gower has two quite distinct phases. One of these, the *Anamosa limestone* occurs in horizontal or slightly undulating layers 8 to 12 inches thick. It is compact and makes an excellent building stone. It is well shown in the stone quarries north of the village of Leclaire. The other phase is the *Leclaire limestone,* which occurs in great masses without distinct bedding, or as inclined layers (Pl. 3, B.) The dip of the beds may vary from 10° to 20° or even more, and the direction of dip often changes greatly within a short distance. It is an excellent rock for the manufacture



A. Bluffs of the Mississippi, one mile north of Savanna, Illinois. The rock forming the cliff is the Niagara limestone.



B. Leclaire limestone showing oblique bedding. Exposed in the river bank a half mile south of Leclaire, Iowa. (Norton, Iowa Geol. Surv.)

of lime, and is used for that purpose at Port Byron. Abandoned kilns are also seen at Leclaire and Princeton. Exposures of the Leclaire limestone are common in the Narrows from Princeton south, and in many of the creek valleys of the neighboring uplands.

Effect Upon Topography.—The Niagara is the great cliff-forming formation of this region. The thick massive beds of its lower part stand as bold cliffs in the bluffs of the northern part of the region (Pl. 3, A.), and wherever a swift stream is cutting into this formation a gorge is formed, as at the mouth of Spencer creek. North of Savanna the weathering of the limestone has produced chimney rocks and towers, some of which have been given individual names as "Twin Sisters," "Indian Head," and "Open Bible," (Pls. 7, B and 8).

THE DEVONIAN SYSTEM.

The Devonian limestone is the uppermost rock about Davenport, and on the Illinois side it underlies Pleasant valley and Rock River valley below Joslyn. Around the base of the Moline upland and at the base of the south bluff of Rock River valley it passes beneath a later formation found in the uplands. Exposures are frequent along the banks of the Mississippi river, from Crow creek southward. The formation is also seen at frequent intervals along Rock river, in the lower courses of Duck and Crow creeks, and in the low cliff around Rock Island. It underlies, at a depth of a few feet, much of the bench between the bluff road and the river from Davenport to Crow creek, and is exposed in a number of the streams which flow across the flat, and in the quarries around Bettendorf.

The series is made up of several formations, each of which has its own distinguishing characteristics. The four lower divisions are grouped together as the *Wapsipinicon stage* (p. 7). They are, in general, fine grained, compact, gray limestones. The rocks outcropping at Bettendorf, in the lower course of Duck creek, and at Cady quarry in the east part of Moline, belong to this stage. The rock is extensively quarried for building and crushed stone both along the bluff east of Davenport and at Bettendorf. The strata dip slightly to the southwest, and at Davenport pass under those of the next higher or Cedar valley stage. This division consists of gray, thin-to-medium bedded limestone and calcareous shale. It is exposed in the quarries in the southwest part of Davenport, and in the gullies of Buffalo township farther west. The strata of this stage have many fossils which may be collected readily in the gullies and quarries of Buffalo township.[1]

THE PENNSYLVANIAN SYSTEM—THE COAL MEASURES.

Extent and Outcrops.—The Coal Measures strata are the youngest of the bed-rocks of the region, and are therefore the uppermost bed-rock formation wherever they exist. This region lies at the northern margin of the great Coal Measures of Illinois, and most of the outcrops with which we are concerned belong to isolated patches which lie north of

1 Norton. Iowa Geol. Surv., Vol. IX, pp. 440-456.

The outlier of Coal Measures strata underlying the upland south of Rapid City formerly furnished considerable coal, but the supply has been largely exhausted, and little is now produced. Abandoned dumps and shafts show something of the former activity. Mining on a small scale has been carried on in Buffalo township, Scott county, and at several other places in the south part of the region.

Contact with Older Beds.—The base upon which the Coal Measures rests is very irregular. It consists of Devonian limestone at the south, while to the north the Coal Measures rests on the Niagara limestone (Fig. 3). Many of the outliers of the Coal Measures lie in depressions or channels in the limestone. At Cleveland, the valley flat of Rock river (570 feet) is underlain by a thin layer of Coal Measures shale, through which mounds of Devonian limestone protrude, while a mile to the southeast, at the same level, a boring is reported to have gone 125 feet in the shale, or down to an elevation of 445 feet without reaching its base. At Island City, beds of shale and sandstone have a thickness of 200 feet, extending 70 feet below the river level. Borings around Argo, on the upland northwest of Leclaire pass through Coal Measures shales, and one well is reported as entering the limestone at a depth of 320 feet. This places the base of the Coal Measures shale at this location at about 440 feet above sea level or 120 feet below the Mississippi river level at Leclaire. Shale underlies the flat between the village of Pleasant Valley and the river, and one well record indicates that it extends at least 70 feet below the river. On the upland in the N. E. 1/4 of Sec. 11, Hampton township, a mining shaft reaches the lower coal seam at a depth of 125 feet or at practically the elevation of the river. The base upon which the formation rests is therefore uneven with a relief of 100 to 150 feet.

Examples of smaller irregularities may be seen in a number of places. In the northwest part of Morrison, the Coal Measures sandstone is quarried at the level of the creek, while a short distance to the northeast the Niagara limestone occurs in the bank 25 to 30 feet higher. In a railway cut between Island City and MacArthurs, the contact of limestone

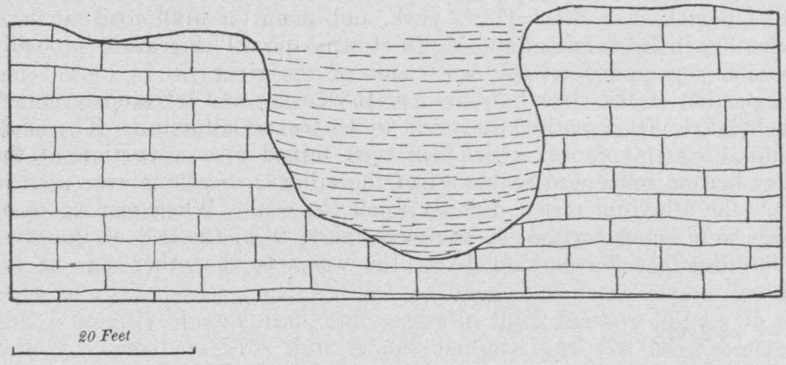


FIG. 5. Diagram showing a pocket of Coal Measures shale in a depression in the Niagara limestone. Exposed in a cut of the I. & I. Electric Ry. between Island City and MacArthurs, Scott county, Iowa.

and shale is very irregular, and pockets of shale extend down into depressions in the limestone (Fig. 5.) Other examples of this irregular (*unconformable*) contact were seen in the Cady quarry at the east line of the city of Moline, in the valleys of Buffalo township, Scott county, and at many other places throughout the area.[1]

THE SUPERFICIAL DEPOSITS.

Everywhere at the surface there appears a deposit of loose material, known as *mantle-rock,* which more or less completely conceals the bed-rock. This mantle-rock will be considered in later chapters.

HISTORY OF THE BED-ROCK FORMATIONS.

The physical history of the region as interpreted from the rocks that may be seen at the surface, would begin with the Maquoketa stage at the end of the Ordovician period (p. 10). But the records of the artesian wells (p. 8) show that the strata which underlie the Maquoketa shale are continuous with the strata of similar age exposed in the Mississippi vallley farther north, and from these sources we may gather some points in this earlier history of the region.

Our knowledge of the area begins with a time (Cambrian period, p. 7) when the whole region was beneath an extensive but shallow interior sea, which stretched from near the present eastern border of the continent westward far beyond the present Mississippi valley. Then, as now, those parts of the continent which were land were being eroded, and the rivers were bringing down their loads of sediment to the seas. The sediments left in this region were for a long time, sands, which were sorted by the waves and currents of the sea, and spread out somewhat uniformly. Then mud became more abundant in the materials brought down by the rivers, and was mixed with the sands in various proportions, or predominated to such an extent as to form mud deposits. At another time the waters became sufficiently clear to allow a large fauna of shelled animals to live, which on dying, added their calcareous shells to the incoming sediments. This formed calcareous muds or calcareous sands, or, if the incoming sediments were at a minimum, nearly pure calcareous oozes were accumulated. In these ways were deposited the more than 600 feet of sediments which now make up the Cambrian strata (p. 7).

The transition from the Cambrian period to the Ordovician was accomplished by a change of conditions which cut off the supply of sand, thus allowing the waters to become clear, and developing conditions favorable for the lime secreting animals. Calcareous oozes and muds then accumulated on the sea bottom to a thickness of more than 300 feet (Oneota limestone). This was followed by a return to the conditions for the deposition of sand, and a wide-spread but thin bed of sand was laid down, forming what is now known as the St. Peter's sandstone (p. 8). The conditions favorable for the formation of limestone re-

[1] Other examples of this irregular surface are given by Professor Norton in his report on Scott county. Iowa Geol. Surv., Vol. IX, pp. 463-465.

turned again, and the materials for the Galena-Trenton limestone were deposited. Whether the Galena-Trenton stage was closed by an emergence of the land, and separated from the Maquoketa by a period of erosion, or whether it merged gradually by continuous deposition into the Maquoketa stage, cannot be told from the facts now known in this region.

During the Maquoketa stage, deposits of mud were being made throughout the region, and from these the Maquoketa shale has been formed. At times the muds received more or less calcareous material, and in some places (Big Cut section, p. 10), this material predominated for short intervals, forming beds of limestone in the shale, or sometimes considerable beds of shaly limestone. During the times of clear seas, life was abundant and the forms were quite varied. Sedimentation was suspended for a time with the withdrawal of the sea in which the mud of the Maquoketa formation was deposited, and the region was then subjected to erosion until the Niagara seas advanced over it about the middle of the Silurian period.

Little mud or sand was brought to the Niagara seas of this region. The waters were clear, and lime secreting animals flourished. The calcareous deposits laid down have formed the massive Niagara limestone. Animal life changed more or less during the long period in which this limestone was being deposited, for the fossils of the lower beds are not the same as those above. In the Gower stage, it appears that the sediments were put down in horizontal beds (Anamosa limestone) in some places, while in others, or at succeeding times in the same places, the deposits were put down as inclined layers (Pl. 3, B.), or sometimes as massive deposits that show little evidence of bedding (Leclaire limestone.) The Anamosa and the Leclaire phases of limestone grade into each other both vertically and horizontally, and either may overlie or underlie the other. They are apparently contemporaneous phases of deposition. The deposits which formed the Leclaire phase were probably formed around the mounds of coral reefs similar to those which now exist in the shallow portions of our tropical seas, while the Anamosa limestone is of material deposited on the more level portions of the sea bottom some distance from the reefs.

After the deposition of the Niagara limestone, the sea again withdrew from this region, and land conditions appear to have prevailed until mid-Devonian time. At least a part of this region, and possibly all of it was then submerged again.[1] The sea was relatively clear, and the calcareous deposits laid down formed the Devonian limestone. Marine life was abundant at various times, and quite varied. This was the last limestone formation of this region. After its deposition, the sea again withdrew, leaving over at least a part of the area, a surface of Devonian limestone.

The erosion interval begun in this region toward the end of the Devonian apparently continued through the Mississippian (Lower Carboniferous) period, making the surface of the land very irregular.

[1] Some beds of questionable Devonian age occur in Jackson county, Iowa. See Iowa Geol. Surv., Vol. III, pp. 122-126, and Vol. XVI, pp. 621-625.

During the Pennsylvanian (Upper Carboniferous) period which followed, deposition took place on this eroded surface. If enough deep well records could be had, it would probably be possible to trace the valleys which existed on the surface before the Pennsylvanian period, by the presence of the Coal Measures which they contain. Unlike the systems of greater age, the Coal Measures deposits were not all of marine origin. They were partly land-water deposits, consisting of muds and sands, possibly partly marine, but largely swamp, valley and lagoon deposits. Vegetation grew in the swamps and lagoons, and on dying, fell down into the stagnant waters and was preserved from decay. In this way, thick deposits of vegetable matter were accumulated, and furnished the material from which the coal has been formed. Some of the shales and sandstones also, were probably deposited in valleys or plains on the land. The Coal Measures may once have extended over most of the area, but if so, they have been removed from the larger part of it by erosion.

The deposition of the Coal Measures in this region was ended by a relative uplift of the land, which caused the areas of deposition to be drained. With this event, the history of the bed-rock formations ends.

CHAPTER III.

THE EROSION INTERVAL BETWEEN THE DEPOSITION OF THE COAL MEASURES AND THE GLACIAL PERIOD.

After the deposition of the Coal Measures, a long period of erosion began in this region. It continued, perhaps with some interruptions, through the Mesozoic era, and up to the Quaternary period of the Cenozoic era (p. 6). Concerning this long lapse of time little can be said in detail, but the general facts are clear. It was a time of conflict between the opposing forces of relative uplift on the one hand, and the processes of erosion on the other.

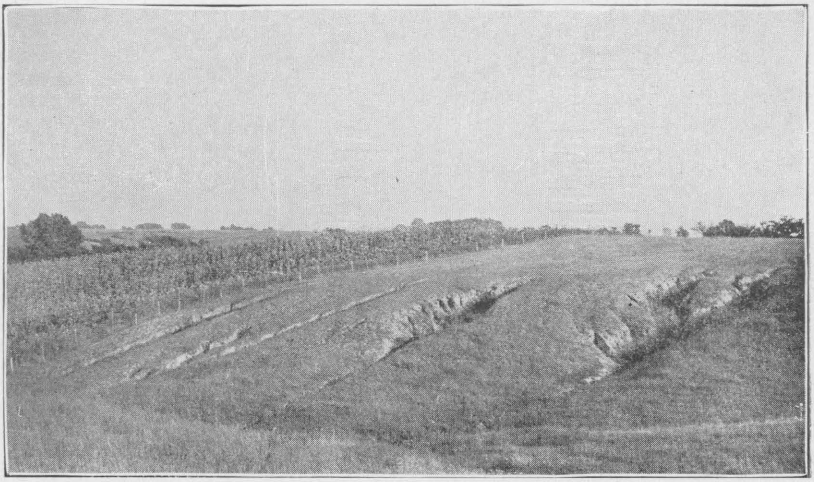
Of the events of the earlier part of the Mesozoic era in this region we have no clear record. There is no evidence of deposition, and it is assumed that erosion was in progress. During the Cretaceous period, deposition may have taken place in this region. Probable Cretaceous deposits have been recognized in Muscatine[1] and Delaware[2] counties, Iowa, and it is possible that the Cretaceous seas extended over much or even all of the region here described; but if so the deposits have been destroyed by erosion. During the Tertiary period, erosion is assumed to have been in progress.

The topography at the end of the Tertiary period, before the invasion of the ice of the Glacial period is known in a general way. It was a topography of considerable relief. There were deep valleys separated by high divides. In some places the valleys were narrow, and the divides wide, while in other places the valleys were wide and the divides relatively narrow. The general character of the surface had been determined by the erosion of running water. That the development of this topography may be clearly understood, a brief statement of the work of streams, and the topographic results which they accomplished, is here introduced.

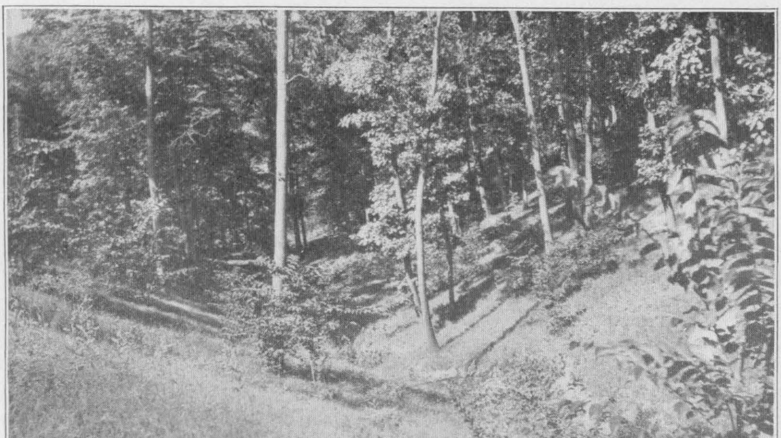
GENERAL STATEMENT OF THE WORK OF STREAMS.

The Origin of Valleys.—The greatest river of this region is the Mississippi, and it occupies the greatest valley. The large tributaries of the Mississippi, the Rock and the Wapsipinicon rivers, are streams of secondary size, and flow in valleys which though large, are smaller than that of the Mississippi. Smaller streams flow in smaller valleys, down to ravines and gullies through which water flows only when it rains. Throughout the whole series from largest to smallest there is a crude

[1] Udden. Iowa Geol. Surv., Vol. IX, pp. 316-320.
[2] Calvin. Iowa Geol. Surv., Vol. VIII, pp. 160-161.



A. Hillside gullies starting on the steepest part of the slope, Scott county, Iowa. (Norton, Iowa Geol. Surv.)



B. Valley in Fejervary park, Davenport, just below the rustic bridge. The V-shaped valley has steep sides and is youthful.

sort of adjustment between the size of the stream and the size of the valley. Each joins its main at the level of the latter, and in turn, receives tributaries whose lower ends accord with its own elevation at the point of junction. From these relations of streams and valleys, we conclude that the valleys were made by the streams which occupy them.

The Carrying Power of Streams.—It is a matter of common observation that streams are more or less muddy. In this region a clear stream is exceptional and this is true both of the small rills that gather during a heavy shower, and of the large streams which never dry up. No sooner does water begin to flow over the ground after a shower than it begins to pick up earthy matter from the soil, making the water muddy. The sort of material picked up depends upon the nature of the soil passed over. Water flowing over slopes of yellow clay picks up material which makes the streams yellow. A black soil yields material which makes the streams dark, and the mud washed from macadamized streets makes the streams gray. Not only does the water flowing down the slopes to streams gather sediment, but the streams themselves wear their channels. The amount of sediment carried by any particular stream may be small, but when we remember that every stream carries some sediment, and has been doing so for ages, we see that enormous quantities of material must have been moved in this way. The result of this removal of sediment is that the valleys in which the streams flow are made larger and the surface of the land gradually lowered, while the material carried away by the streams is left farther down the valleys, of in the sea to which the valleys lead.

The Mississippi is estimated to carry to the Gulf of Mexico enough material each year to cover a square mile to a depth of 268 feet, or about 7,500,000,000 cubic feet. To carry this material to the Gulf by rail would require that a train of forty-four loaded cars arrive at the Gulf each minute.[1] If one-fifth of this is gathered in the Mississippi basin in or above our area, we get some idea of the amount of material carried by the Mississippi in this part of its course, that is, an amount equal to what would be carried by trains of forty-four loaded cars each, passing at the rate of one each five minutes. A very large proportion of this is carried in times of flood, but some is passing all the time.

The Beginning of a Valley.—A land surface emerged from the sea would not have valleys like those found on the land. Its surface would be rather smooth, but it would probably have some slight irregularities and some slope. Rain water falling upon such a surface would gather in the lower places and flow along them down the slope. As more water flows along the low places than elsewhere, erosion would be more rapid in them. Where the flow of the water is swift, gullies would begin to develop, just as they do on many a hillside at the present time, often to the injury of farmland (Pl. 4, A.) Each succeeding fall of rain would make the gullies larger by increasing their length, width and depth. In course of time the gullies would grow to be ravines, and the ravines grow into valleys.

[1] In this computation the specific gravity of the sediment is taken as 2.5 and the capacity of a railway car as 50,000 lbs.

Tributary Valleys.—As a gully grows, tributary gullies are developed on its slopes by the water entering it from the sides. These tributary gullies grow with each succeeding shower, and increase in length, width and depth. Tributaries of the second, third and higher orders will follow. A main valley with all its tributaries is called a *valley system.* The smaller valleys join to form larger ones as they are followed down the slope, while in the opposite direction they divide into smaller and smaller branches which in time extend to every part of the land surface.

The Base-Level of Streams.—A stream which flows to the sea may cut the lower end of its valley to sea-level, and a stream which flows into another stream may cut the lower end of its valley down to the level of the stream it joins. Back from its mouth the stream flowing to the sea cannot lower its valley to sea-level, but only toward it. Similarly the tributary stream can bring its valley down to the level of its main, at its mouth only. Farther up stream, the valley always rises, though it may be very gradually.

The lowest level to which a stream can bring its valley is called *base-level.* When a stream has reached base-level therefore, it can deepen its valley no more, so long as conditions remain as they are. A stream reaches its base-level first at its mouth, and later at successive points farther up its course.

The Development of a Valley.—During the early stages of a valley's development, erosion will be rapid on its bottom, and it will increase in depth rapidly. If it is in a region of slight relief, the stream can make only a shallow valley before it reaches its base-level; but if the relief is great, it will cut a deep valley before it reaches its base-level. If the region is high, the gradient of the stream will be steep, giving it a high velocity. In the early stages of its development, the valley will be narrow, for the deepening of the valley goes on faster than the widening. The valley walls will be steep, the angle varying with the nature of the material in which the valley is cut. If the material is unconsolidated, as the glacial drift of this region, the valley sides can be only steep slopes; but if the material is a resistant rock formation, the valley sides may be precipitous or even vertical cliffs. A valley in an early stage of development is known as a *youthful valley.* Its V-shaped cross-section is shown in Fig. 6, *a, a' and b, b'*. The valleys shown in Figures 7 and 8 are youthful valleys.

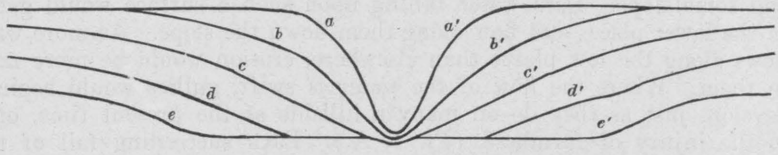
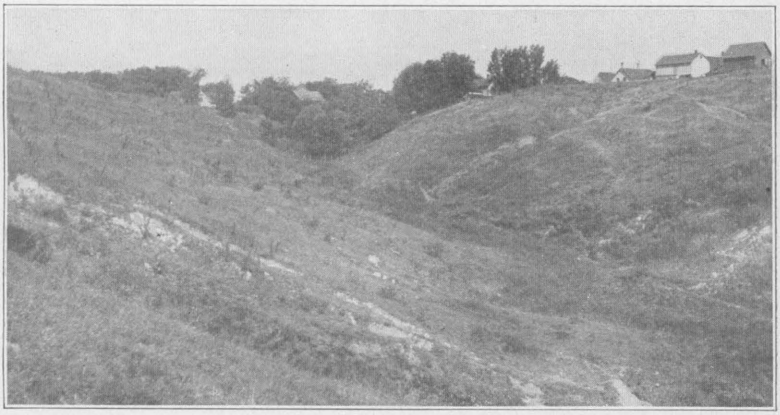


FIG. 6. Generalized cross-sections showing various stages of valley development.

Youthful valleys are found in many places throughout this region. Especially striking examples are found along the bluffs separating the lowlands from the uplands. Illustrations of youthful valleys cut in loess and drift occur along the bluff between Rock Island and Moline



A. Steep sided valley in the northwest part of Davenport. It is further advanced than shown in Plate 2-B, but is still youthful.

B. Valley in the east part of Davenport. The sides are gentler than in A, but the bottom is narrow and the valley is youthful.

and in Fejervary park at Davenport (Pl. 4, B.) The gully in the buffalo field in Fejervary park is an excellent example of a very youthful valley. Good illustrations of narrow gorges bounded by vertical rock walls are found at the mouths of Duck and Spencer creeks, Scott county, Iowa, and along Carroll creek, from Mt. Carroll, Carroll county, Illinois, west to its union with Plum river.

After a stream reaches base-level and ceases to deepen its valley, the processes of valley widening may still go on. At this stage the valley has a gentle gradient, and the stream is easily deflected from side to side. The stream undercuts its banks in some places causing them to retreat, thus widening its valley. In general the slopes become less steep, as the growth of the valley progresses. Valleys at this stage of development are known as *mature valleys*. A cross-section of a mature valley is shown in Fig. 6, *c, c'*. The passage of a valley from the youthful to the mature stage is gradual. Plates 4, B., 5 and 6 show progressive stages in valley development.

Mature valleys occur throughout the region described in this bulletin. Apart from the valleys of the larger streams, they are best developed in the area northeast of Savanna, and in Clinton county northwest of Clinton. Mature valleys may occur in the same general region with youthful valleys, and the tributaries of mature valleys are often youthful. The stage of development of a valley is usually more advanced in its lower course than farther up the stream, and the same valley may present a succession of stages of development as it is followed toward its head.

As erosion continues beyond the stage of maturity, a valley becomes wider and wider, and its slopes on the whole more gentle. The sluggish stream meanders slowly over its broad flat, under-cutting its banks in some places, but on the whole doing little eroding. A later stage of valley development is the *old age stage*. The cross-section of an old valley is shown by the lower profiles of Fig. 6.

The Cycle of Erosion.—A region with youthful valleys would have much surface which is not yet invaded by erosion channels. Much of

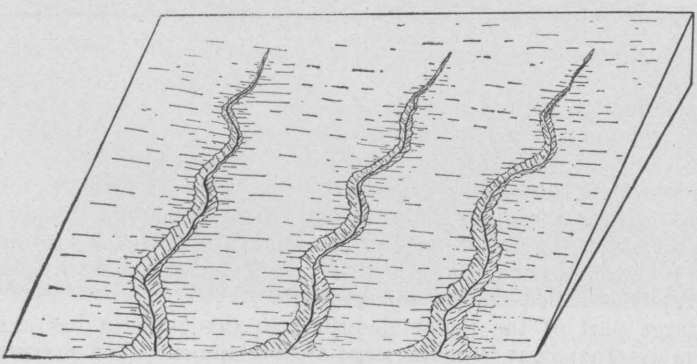


FIG. 7. Diagram showing a land surface with only a few valleys. (Chamberlin and Salisbury.)

the surface remains at its original level, forming broad inter-valley areas. A region of this character is shown in Figs. 7 and 8. The topography of such a region is called *youthful topography*.

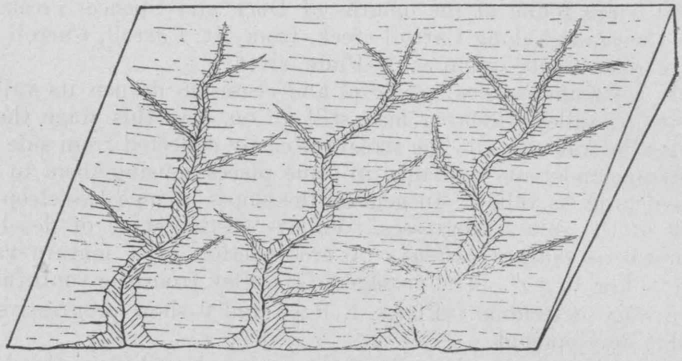


FIG. 8. Diagram showing the dissection of the upland shown in Fig. 7, by tributary valleys. (Chamberlin and Salisbury.)

Examples of youthful topography are found at a few places within this region. In southern Clinton county there is an area that has not been greatly affected by erosion, and it furnishes the best example of youthful topography found within the region. Other areas of the same class occur on the uplands farthest away from the great valleys, as in Scott county, north of Davenport, and on the Moline upland (Pl. 7, A.)

A profile across several valleys, and the broad inter-valley areas of youthful topography is shown in Fig. 9 *a, a', a''*. As the valleys are widened the flat-topped divides are correspondingly narrowed, until they become ridges *b, b', b''*. Further erosion will reduce the elevation of the divides until the region become almost level *d, d', d''*.

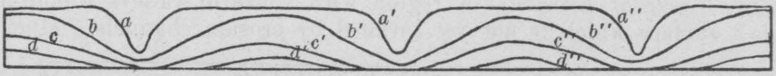
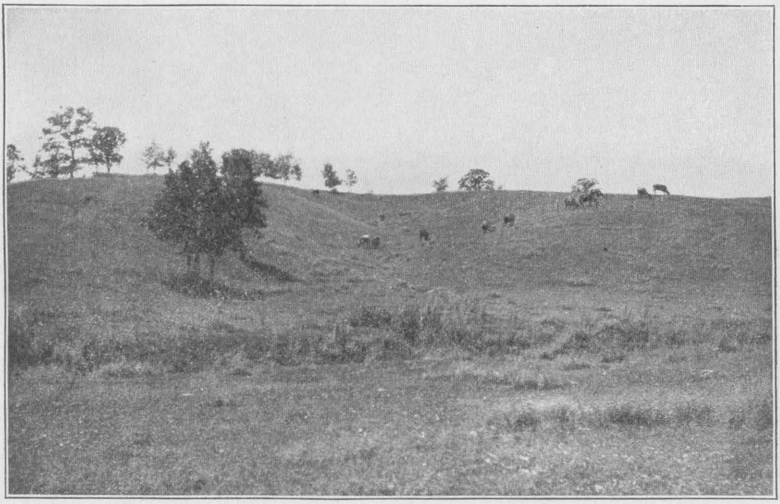


FIG. 9. Cross-sections showing various stages of erosion in one cycle.

The reduction of a region to base-level however, does not take place by the widening of a few valleys. Tributaries develop from the main valleys, and cut back into the inter-valley areas (Fig. 8) and in time the whole area is cut up (dissected) by valleys. The level upland is reduced to narrow ridges, slopes extend from the narrow divides to the streams, and the greatest possible amount of the surface is in slopes (Fig. 10). The dominant valleys of such a region are mature, and the topography is called *mature topography*.

A large part of the region described in this bulletin has a mature topography, that is, it is in the stage of development when slopes greatly predominate over the flats of the upland or the flats of the valleys. The

A. A valley in the southeast part of Moline. The sides are steep but the beginning of a flat is seen.



B. A valley in the northwest part of Davenport, showing a broad valley bottom in which the stream has a shallow channel. This is a stage of development in advance of that in A.

best illustrations of mature topography are seen in Carroll county, Illinois, north and northeast of Savanna, and in northern Clinton county, Iowa. Mature topography is also found in Whiteside county north of Union Grove, on the Garden Plain upland, in the northern part of the Coe upland, and around the margins of the other upland areas of the region.

Erosion beyond the stage of maturity reduces the steepness of the slopes, and develops wide flats at the base-levels of the streams. Flats develop first along the main streams, and later extend into the tributary

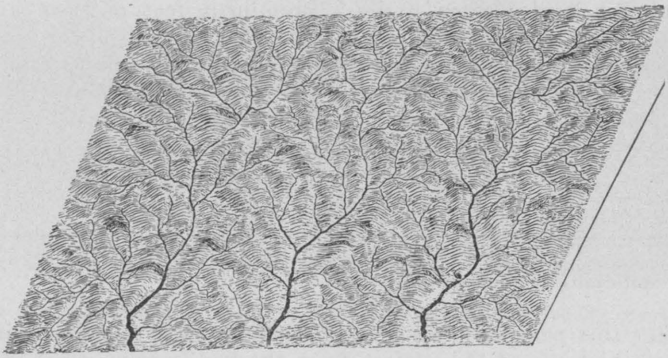


FIG. 10. Diagram showing a thoroughly dissected region with many valleys. (Chamberlin and Salisbury.)

valleys from their lower ends. The development of flats along main streams may begin while the topography is still youthful, and the flats of main streams may become wide in maturity; but as the valleys advance to old age, the areas of lowland represented by the valley flats are so large that they exceed the uplands in size. When the divides become narrow and low, the topography of the surface has become old. A surface in old age is almost level. Such a surface is called a *peneplain* (an almost plain). If the process goes on so that the whole region drained by a river system is reduced to base-level, the area becomes a *base-leveled plain.* Peneplains grade into base-leveled plains. The period of time necessary for the reduction of a surface to base-level, is a *cycle of erosion.* In the early stages of an erosion cycle the region is made rough, but the final result of stream erosion is a smooth surface. The slopes of maturity are developed at the expense of the level upland areas of youth, and the lowland plains of old age at the expense of the slopes of maturity.

When a region is base-leveled, erosion is practically stopped. The streams wind about over the low plain to which they have reduced the surface and flow slowly to the sea. So long as the land remains stationary at that elevation this condition continues. But if the land is raised with respect to sea-level, the flow of the streams is quickened, and they cut new valleys in the former flat plain. This inaugurates a new cycle of erosion.

THE PRE-GLACIAL TOPOGRAPHY OF THE REGION.

It was noted at the beginning of the chapter (p. 22) that the chief event within this region during the Mesozoic era, and the early part of the Cenozoic era was erosion. The time represented by these eras is probably many millions of years. As a result of this long continued erosion, this region was base-leveled, or peneplained, at least as early as the latter part of the Tertiary period. This old plain, now uplifted, is represented by the summit plains of this region, which have a great uniformity of elevation as shown in Figs. 3 and 11. This uniformity of summit level is seen to be a prominent feature from any of the highest elevations of the region, where a large extent of the country may be seen. It forms the even sky line of Jackson and Clinton counties, Iowa, and of Carroll county, Illinois.

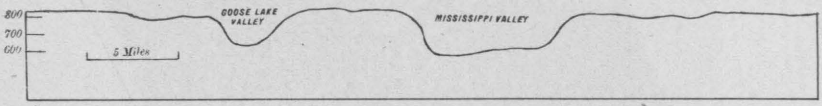
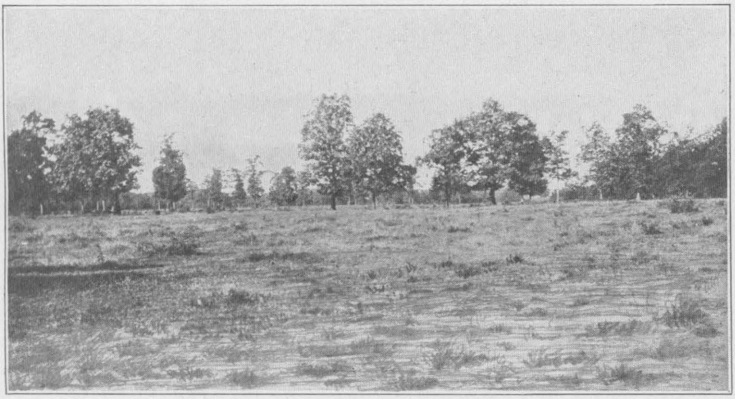


FIG. 11. Generalized surface profile on an east-west line, showing the approximate uniformity of summit levels.

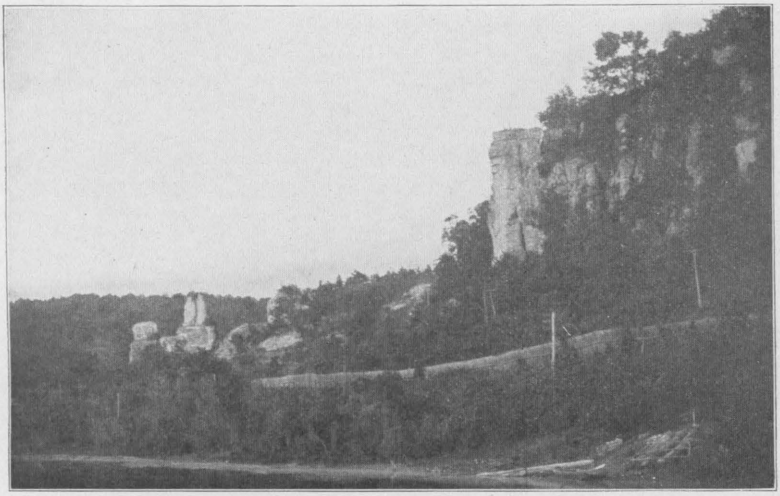
After this peneplain was developed, there was relative uplift of this region which raised the surface from the low level to which it has been reduced by erosion, to an elevation of 700 to 900 feet or more. With this elevation, a new cycle of erosion began. The quickened streams began to cut new valleys in the level upland surface (the raised peneplain) and it was dissected to the stage of early maturity before the beginning of the Pleistocene period. The relief was 300 to 400 feet, the rivers flowed at a level below that of the present streams, the slopes of the valleys were steep and covered with only a thin veneer of decayed rock, and the whole country was more rugged than at present.

Before the ice of the glacial period developed over North America for the last time, the Mississippi river flowed at a level 150 to 200 feet below its present channel. This is known because there is a filling of glacial sand and gravel to that depth in the bottoms of the valley. In the northern portion of this region, this greater depth brought the valley bottom down to the horizon of the lower part of the Maquoketa shale or the top of the Galena-Trenton limestone. The Maquoketa shale extended to 200 to 300 feet above the river, and was overlain by the massive Niagara limestone. The shale was easily removed by the lateral erosion of the river, and the projecting layers of the overlying Niagara limestone, broke off in great blocks which fell to the base of the cliff and were worn away by the abrasion of the river. These conditions of structure, position, and unequal resistance of the formations, resulted in a rapid retreat of the valley walls, and the development of steep bluffs.

In the vicinity of Lyons, the Maquoketa shale dips to the south and within two miles the upper contact has dropped more than 100 feet



A. Nearly level surface of the Moline upland, unaffected by stream erosion.



B. The Illinois bluff, one and a half miles north of Savanna. In the background, is the feature known as "The Twin Sisters" and to the left of this, the "Open Bible."

below the river. With the disappearance of the Maquoketa shale, the steep, high bluffs which are so prominent in the northern portion of the region come to an end, and the Mississippi valley soon contracts to less than half its former width. This is shown on the topographic maps. (Pl. 1 and 2).

THE UNGLACIATED AREA NORTH OF SAVANNA.

Over most of this region the pre-glacial topography was much changed by the ice of the glacial period, but the area north and northeast of Savanna was not glaciated, and here the pre-glacial topography as modified by the erosion of the Pleistocene period still remains. The area which was not glaciated differs from the rest of this region, both in topography and in the nature of its surface materials.

Topography.—The divides north of Savanna rise to an elevation of more than 900 feet above sea-level reaching more than 960 feet about 10 miles north of Savanna. The valley bottoms here have an elevation of 600 to 700 feet, thus giving to this area a relief of 200 to 300 feet and more, the greatest within the region. The creek valleys are deep and steep sided and have narrow flood-plains. The valleys and ravines tributary to the main creeks have thoroughly dissected the region by their numerous branches, which now head near each other on opposite sides of the narrow ridge-like divides. In the development of the valleys, the remnants of the upland have been narrowed to ridges. The flood-plains have not yet developed notable width so that a large part of the surface is in slopes. The area north of Savanna is a good example of a thoroughly dissected upland plain, and is in striking contrast with the more even country to the south.

The bluffs of the Mississippi north of Savanna (Pl. 3, A) and the rock gorges of Carroll creek and Plum river are the best developed features of their kind found within the region. The bluffs north of Savanna often rise in vertical walls 100 feet or more, and the total height of the bluffs above the river is 150 to 250 feet. The tops of the cliffs are sometimes adorned by fantastically weathered columns and turrets, which stand out free from the cliff face. One and a half miles north of Savanna, at the Snyder lime kiln, several of these erosion remnants, because of their real or fancied resemblance to the object indicated have received such names as "The Twin Sisters," "Indian Head," and "Open Bible" (Pls. 7, B. and 8.)

Effect of Topography.—The region north of Savanna is sparsely populated, for much of the surface is in slopes too steep and rocky for cultivation. The loess soils of the divides, and the alluvium of the narrow flood-plains furnish the best farming lands, while the steep slopes are given over to pasture and timber.

As may be seen from the topographic map (Savanna sheet), the roads of the region are very crooked, and have had their courses determined by the topography. For the most part they follow divides, or, in a few cases, valleys. Railways avoid the region whenever possible, running around the margin of the rough tract, as in the case of the C., M. & St. P. Ry. from Mt. Carroll to Savanna, or they follow the main valleys.

Superficial Deposits.—The material of the surface here, as elsewhere, is a yellowish loam called *loess* (p. 3). It overlies the divides, where it often has a thickness of 15 to 20 feet; but on the steeper slopes it is usually absent, or thin and patchy. The loess sometimes rests directly upon the solid bed-rock; but over most of the area there is a band of weathered rock at its base. This is the product of the weathering (decay) of the bed-rock, before the loess was deposited. This weathered rock material is therefore local in origin, and contains only those constituents found in the bed-rock. It grades downward into decayed rock, which in turn grades into the solid rock below (Fig. 12).

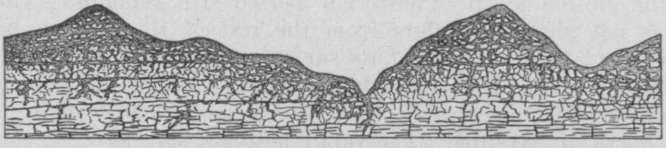
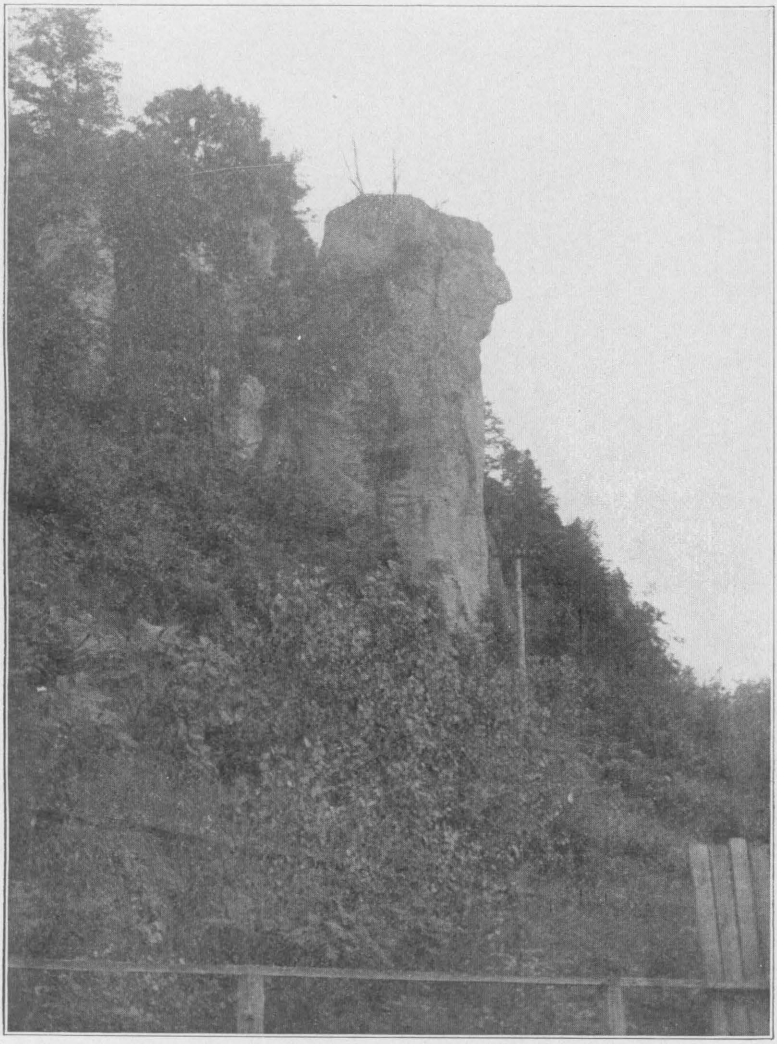


FIG. 12. Diagramatic section in the driftless area, showing relation of the mantle-rock to the solid rock beneath. (Alden, U. S. Geol. Surv.)



The "Indian Head" as seen from the north. One and a half miles north of Savanna.

CHAPTER IV.

THE QUATERNARY OR PLEISTOCENE PERIOD.

GENERAL STATEMENT.

THE PLEISTOCENE ICE-SHEETS OF NORTH AMERICA.

In the preceding chapter, the history of the area was traced down to the beginning of the Pleistocene period. With the advent of this period, a new and remarkable succession of events began, for during its progress great thicknesses of snow accumulated over the northern part of the continent, burying the land to great depths. In the course of time the snow was compacted into ice, so that the snow-field became an ice-field or *continental glacier.* Epochs of cold with heavy precipitation of snow, alternated with periods of more genial climate when the snow and ice were largely or wholly melted. The history of this period, therefore, includes *a succession of glacial epochs alternating with a succession of interglacial epochs.*

The ice of these great glaciers spread radially from the centers of accumulation on the highlands east and west of Hudson Bay (Pl. 9), and at the time of their maximum extension, covered some 4,000,000 square miles of land in the northeastern part of the continent. At this time the ice reached the Atlantic east of New Jersey, while in the interior of the continent its margin corresponded roughly with the present courses of the Ohio and Missouri rivers.

THE EXTENSION AND WITHDRAWAL OF AN ICE-SHEET.

In the history of an ice-sheet there is (1) a general period of growth or extension in which the advance of the ice exceeds the waste by melting and evaporation, and (2) a period of decadence or withdrawal in which the waste exceeds advance. Within the general period of extension there may be short intervals when the ice-margin is stationary or when it retreats temporarily and within the general period of withdrawal there may be short intervals when the ice-margin is stationary or even makes a slight readvance. Between the general stages of advance and retreat there may be a stage when the ice-sheet remains essentially constant in size.

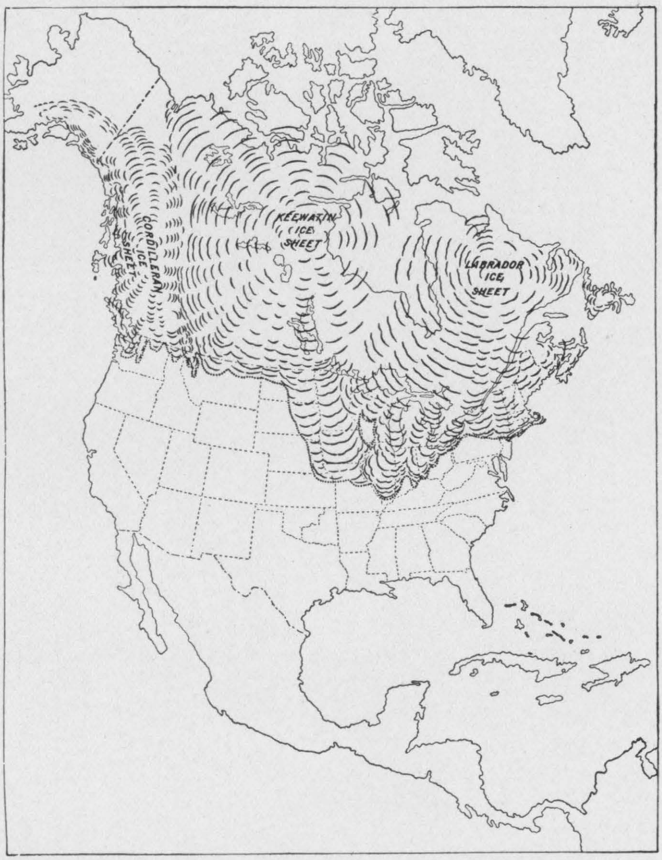
An ice-sheet increases in area partly by growth from the accumulation of snow about its edge, and partly as a result of its own motion. We need not discuss here the nature of this motion. It is sufficient for our purpose to say that the motion of a continental glacier results in a slow spreading of the ice from the center of accumulation.

In thinking of the motion of an ice-sheet we must distinguish between the movement of the ice itself, and the change in position of its margin. The margin of the ice is being pushed forward constantly by the pressure of the thicker part behind; but the margin of the ice is always being wasted by melting and evaporation. The advance and retreat of the margin of the ice depends upon the relation of these two factors, forward motion, and marginal wastage. If the forward movement of the ice exceeds the waste of the margin, the edge advances; but if the forward movement is less than the waste, the margin retreats. If the two factors exactly balance, the margin remains stationary. A retreat of the ice-sheet does not mean the backward movement of any part of the ice in the direction from which it came, it merely means that marginal waste exceeds forward movement.

THE SUCCESSION OF ICE INVASIONS AND HOW KNOWN.

"It was formerly thought that there was but a single ice invasion of brief duration, followed by a rapid retreat attended by great floods arising from the melting of the ice; but the more careful studies of later years have revealed a series of invasions separated by very considerable intervals. It is not yet known how far the ice retreated between the advances, but there is convincing evidence that some of the intervals were long, much longer than the period which has elapesed since the last ice retreated. There is also good evidence that in some of them the climatic conditions became at least as mild as they are today. While there are differences of view with reference to the entire disappearance of the ice-sheet from the plains of Labrador and Keewatin, and respecting the estimate to be put upon the importance of the interglacial intervals, the above statements are fully justified by the data now accumulated. Besides the greater advances and retreats, there were numerous halts or oscillations which probably affected the oncomings as well as the retreats of the ice.

"The proofs of the interglacial intervals and the evidences of their duration are found in the surface changes which were wrought by drainage after the deposition of one sheet of drift, and before the deposition of the next; in the depths to which earlier sheets of drift were leached and oxidized by weathering before the deposition of later ones upon them; in the accumulation of peat, soil, etc., now found between



Sketch map of North America, showing the area covered by the ice at the time of its maximum extent, the centers of ice accumulation, and the driftless or unglaciated area in adjacent parts of Illinois, Wisconsin and Minnesota. (Alden, U. S. Geol. Surv.)

different sheets of drift; and in some cases in the changes of topographic attitude which intervened between the deployment of successive ice-sheets.

"The following are the American stages of the glacial period now recognized in the interior of North America, numbered in the order of their age:

XIII. The Champlain sub-stage (marine).
XII. The glacio-lacustrine sub-stage.
XI. The Later Wisconsin, the sixth advance.
X. The fifth interval of deglaciation, as yet unnamed.
IX. The Earlier Wisconsin, the fifth invasion.
VIII. The Peorian, the fourth interglacial interval.
VII. The Iowan, the fourth invasion.
VI. The Sangamon, the third interglacial interval.
V. The Illinoisan, the third invasion.
IV. The Yarmouth, or Buchanan, the second interglacial interval.
III. The Kansan, or second invasion now recognized.
II. The Aftonian, the first known interglacial interval.
I. The sub-Aftonian (pre-Kansan), or Jerseyan, the earliest known invasion.

"These stages were by no means equal, the earlier being markedly longer than the later. There was something like geometrical gradation from the earliest and longest, to the latest and shortest.[1]

THE WORK OF AN ICE-SHEET.

"The surface over which the ice-sheets moved is believed to have had a topography which had been shaped, so far as details are concerned, by rain and river erosion, and was covered by a layer of mantle-rock which originated in the formations beneath. The ice removed this mantle of decomposed material, and cut deeply into the undecayed rock beneath. The best rough measure of the ice erosion is the great body of drift, much of which is composed of rock debris, which lay beneath the decayed horizon at the surface. In effecting this erosion, the ice modified the pre-existing topography to some extent, for weaker terranes (formations) were eroded more than resistant ones, and the topography favored more forcible abrasion at some points than at others, while the ice itself was more effective at some times and places than at others. One of the results was the development of rock-basins by the ice-sheets. On the whole, the topographic effect of glacial erosion was probably to soften the surface contour, without noticeably diminishing the relief. The erosive effect of an ice-sheet of large size is probably greatest toward its edge, but far enough back for the ice to be thick. The position of the area of greatest erosion probably shifted with the decline of the ice-sheet.

"The second great phase of the work of the ice was the deposition of the drift. Some of it was deposited while the ice-sheets were growing, some of it after they had attained their growth and before decay had begun, and some of it while they were declining. Some of it was de-

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1 Chamberlin and Salisbury, Earth History, Vol. III, pp. 382-383.

posited beneath the body of the ice, and some of it at its edge. In some places, water played an important role in modifying the drift left by the ice, while in others its influence was nil. The deposition of the drift altered the topography notably, especially where the drift was thick and the relief of the underlying rock slight. It is to the inequalities of the thickness of the drift than many of the peculiar depressions and elevations of the surface of the drift are chiefly due. Erosion and the deposition of the eroded material are then the two great results of an ice invasion, so far as the solid part of the earth is concerned.[1]

RELATION OF THIS REGION TO THE ICE-SHEETS.

The region under discussion lies in the heart of the great area covered by the ice-sheets (Pl. 9), but the area north and northeast of Savanna which was described on pp. 29-30, is part of an area which was not covered by the ice of any one of the glacial epochs. This is known, because *glacial drift* (the deposits made by the ice) is absent. Because of the absence of drift, the unglaciated tract is called *driftless area.* The driftless area is in marked contrast with the *drift covered* or glaciated lands about it. The general location of the driftless area is shown in Pl. 9. Its total area is 8,000 to 10,000 square miles.

The exact boundary between the drift covered and the driftless areas is not readily traced, for the drift is very thin and patchy near its edge, and it is covered and often concealed by the loess. The approximate boundary is shown on the accompanying map (Savanna sheet, Pl. II).

The larger part of the region described in this bulletin, including all of the area west of the Mississippi and all that east of the Mississippi south of the driftless area, was covered by one or more of the ice-sheets. The ice of all the epochs came from the north, and in the northern part of the continent each ice-sheet formed a broad continuous expanse of ice. The margin of the ice was lobate and certain lobes pushed farther south than the intervening parts. Within each of these lobes the general motion was to the south, but the ice spread laterally from the axis of each lobe and near the sides of a lobe, it sometimes advanced southeast or southwest or even east or west. When a lobe of a great ice-sheet advanced south across Illinois, the ice entered this region from the east, or southeast, but when the ice pushed into the region from Iowa, its movement here was from the west or northwest. The lobate margin of the great continental ice-sheet is shown in Pl. 9, and the direction of motion in this region at successive times is shown in Figs. 13, 15 and 16.

THE SUCCESSION OF GLACIAL EPOCHS AFFECTING THIS REGION.

THE PRE-KANSAN GLACIAL EPOCH.

The first ice-sheet now known is called the *pre-Kansan ice-sheet,* and the drift it left is the *pre-Kansan drift.* The exact extent of this ice-

[1] Chamberlin and Salisbury, Earth History, Vol. III, pp. 358-359.

sheet is not known, for its drift was completely covered by later ice-sheets. Pre-Kansan deposits have been recognized beneath deposits of later age over much of southern Iowa, and several well records of western Scott county[1] indicate an eastward extension of this ice-sheet near to our area, and it may have extended across it into Illinois, advancing from the west.

THE AFTONIAN INTERGLACIAL EPOCH.

The pre-Kansan glacial epoch was followed by an interval when the ice receded from this region, and when vegetation grew upon the surface of the pre-Kansan drift. This interval of mild climate is known

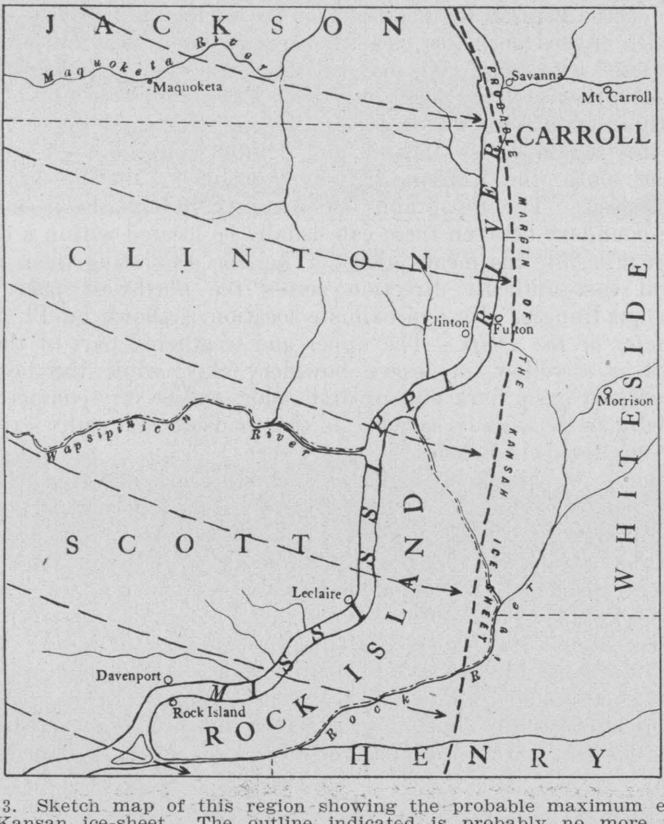

FIG. 13. Sketch map of this region showing the probable maximum extension of the Kansan ice-sheet. The outline indicated is probably no more than an approximation.

as the *Aftonian epoch*. Deposits of this epoch, soil, vegetable matter, stream sand, etc., are shown in the well records of western Scott county.[1]

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1 Norton. Iowa Geol. Surv., Vol. IX, p. 473.

THE KANSAN GLACIAL EPOCH.

The second known glacial epoch is called the *Kansan epoch,* because the ice then reached the northeastern part of Kansas. The drift left by this ice-sheet is called the *Kansan drift.*

Area Covered.—The Kansan ice-sheet entered this region from the west and northwest and advanced southeast toward the Mississippi. At the time of its maximum extension it covered most of the region as shown in Fig. 13.

Area of Exposed Kansan Drift.—The Kansan drift was deposited over all the area covered by the Kansan ice-sheet (Fig. 13.) But later ice-sheets covered a part of the same area, and mixed up the Kansan drift with their own, or buried it beneath their own deposits. The area over which the Kansan drift appears at the surface is therefore the area over which it was deposited, less the area where it was buried by the drift of later ice-sheets. We may call the area where the Kansan drift is exposed or covered by loess only, the *Kansan drift-plain.* Its area within this region is shown on Pl. I. To the north and west it extends beyond this region across Jackson and Clinton counties.

On the south, the Kansan drift is overlain by the Iowan, a later glacial deposit. The topography of the two drift-plains is so unlike that the boundary between them can usually be located within a distance of half a mile, by this means alone. The line separating them runs in a general east-southeast direction across the northwest part of the Cordova quadrangle. Its approximate location is shown on Pl. I.

Character of the Drift.—The upper and weathered part of the Kansan drift is a yellow, or brown bowldery clay, while the lower unweathered part has a dark blue or drab color, and is very compact. The weathered zone is usually as deep as the roadside and gully exposures, and the unaltered drift below is rarely seen.

The limey or calcareous material (calcium carbonate) of the drift has been removed from the weathered zone by the water which has percolated through it. This process is called *leaching.* The calcareous material may be detected by putting a few drops of hydrochloric (muriatic) acid upon it. If it bubbles freely (*effervesces*) calcium carbonate is present. If no effervescence takes place, this material is absent. The extent to which the drift has been leached of its calcium carbonate gives some idea as to its relative age. Gravel and stones are abundant in this drift, and are usually dark colored igneous rocks.

The thickness of the drift is greatest on the divides, where it often exceeds 100 feet, with occasional records of as much as 200 feet. A

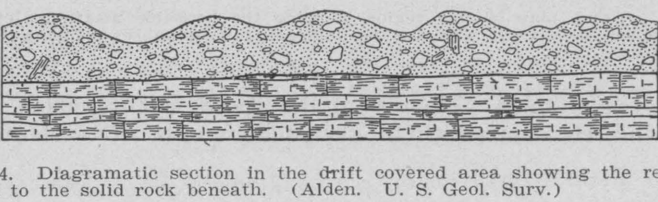
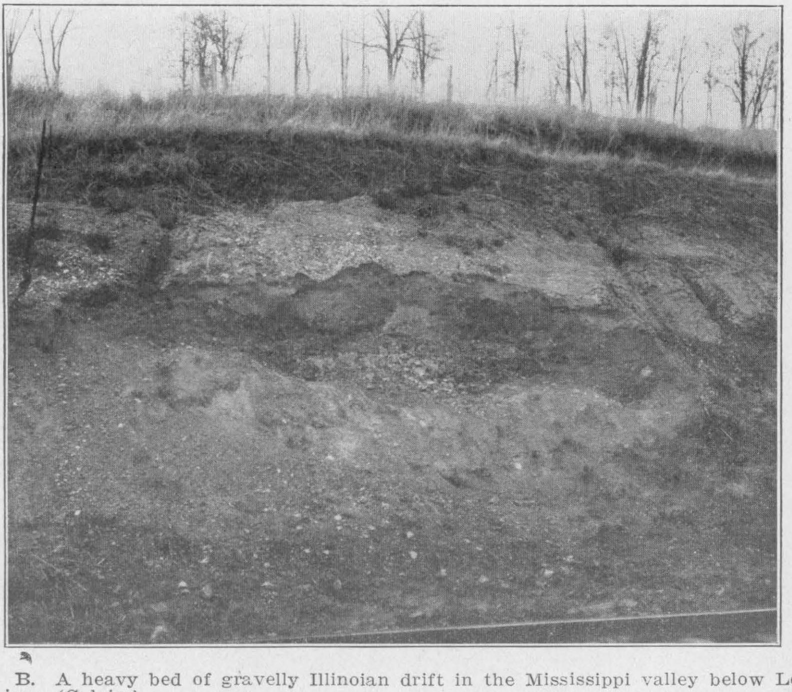


FIG. 14. Diagramatic section in the drift covered area showing the relation of the drift to the solid rock beneath. (Alden. U. S. Geol. Surv.)

A. Gravelly Illinoian drift resting upon a well cemented stratum of gravel (projecting layer) which, in turn, rests upon a deposit of ferruginous sandy clay at the base of the cut. (Calvin.)



B. A heavy bed of gravelly Illinoian drift in the Mississippi valley below Leclaire. (Calvin.)

mantle of loess 10 to 20 feet thick overlies the divides, but on the slopes it is much thinner, and sometimes absent. Here the drift appears at the surface. Exposures of drift are frequent along stream courses and on the steeper slopes, and road cuts often show the drift below 3 to 5 feet of loess or loam. The drift rests directly upon the bed-rock by a sharp contact, and the upper surface of the rock is often planed off smooth (Fig. 14).

The Topography of the Kansan Drift-Plain.—The effect of the Kansan ice-sheet upon the surface must have been to reduce its relief, and when the ice withdrew, it probably left a plain without strong relief. But the Kansan drift plain is now well dissected, with many streams and valleys, and it therefore shows the effect of long continued erosion. The relief is usually 100 to 150 feet, and the valley slopes are moderately steep. The divides between the valleys are rather narrow and irregular, and from them one may look down on either side over the broad flaring valleys. The Kansan drift plain is the most rugged part of the glaciated area, and most nearly approaches the topography of the driftless area, north of Savanna. However, the relief of the Kansan drift-plain is less than that of the driftless area, and the slopes on the whole less steep. Good examples of the well dissected Kansan plain may be seen on either side of the Goose Lake valley in the northwestern part of the Cordova sheet (Pl. I.) The topography of the Kansan drift-plain is, as a rule, mature.

The extent to which this drift is leached, and the well advanced erosion of its surface show that the Kansan drift is of far greater age than the Illinoian and Iowan drifts to the east and south.

THE YARMOUTH INTER-GLACIAL EPOCH.

After the Kansan ice-sheet disappeared from this region, there followed a long interval of time known as the *Yarmouth or Buchanan interglacial epoch*, when the climate was mild. The Kansan drift has suffered far more erosion than the drift of the next glacial epoch, and the difference must be due to the erosion of the Yarmouth epoch. By the most conservative estimate the duration of the Yarmouth must be measured in tens of thousands of years.

This epoch was primarily one of erosion, not one of deposition, so far as this region is concerned. Yet a few deposits referred to this time occur within this region. A short distance southwest of the Tile Works, south of Leclaire, Scott county, Iowa, a cut of the I. & I. Electrict Ry. exposes a stratum of well cemented, horizontally bedded gravel, below Illinoian drift (Pl. 10, A, and 13 A.) This gravel is probably of Yarmouth age. It rests upon ferruginous sandy clay below. A buried soil horizon of this age is known from the records of several wells which pass through the Illinoian drift on the upland of Scott county, Iowa. As the inter-glacial deposits would be especially subject to the erosion of the next ice-sheet, their preservation would be the exception rather than the rule.

THE ILLINOIAN GLACIAL EPOCH.

The drift of the next glacial epoch is best known in Illinois, and for this reason is called the Illinoian drift and the ice which made it the Illinoian ice-sheet. The area over which this drift appears at the surface will be called the *Illinoian drift-plain.*

Area Covered.—The Illinoian ice-sheet approached this region from the northeast, and advancing in a general southwest direction spread over the eastern and southern portion of the area. Its distribution within this region at the time of its maximum extension is shown in Fig. 15. To the east it extended beyond Illinois, and to the west it crossed the Mississippi river, and advanced a short distance into Iowa.

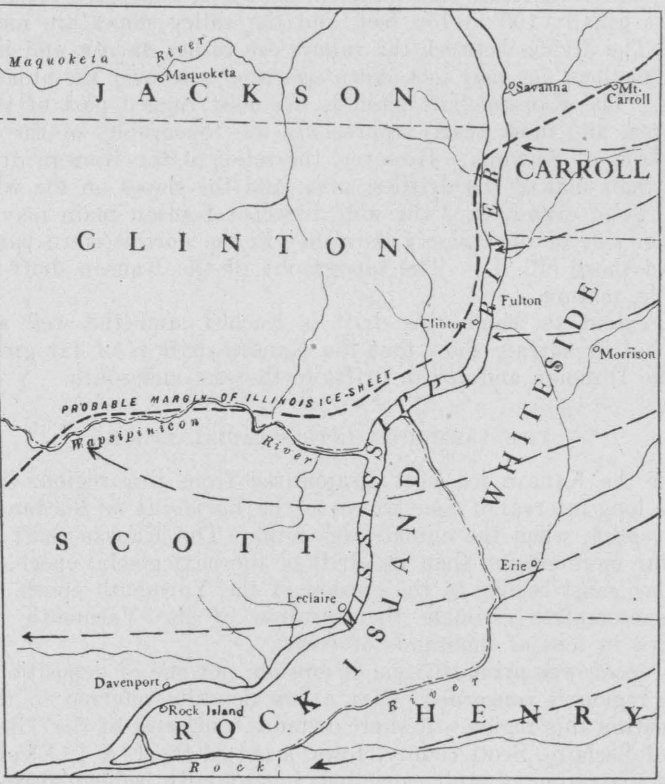


FIG. 15. Sketch map of this region showing the approximate maximum extension of the Illinoian ice-sheet.

Area of Exposed Illinoian Drift.—A small area is southeastern Clinton county, Iowa, which was probably covered by the Illinoian ice-sheet (Fig. 15) was again glaciated during the Iowan epoch. With this exception, and possibly another area southwest of Morrison, Illinois, the Illinoian drift-plain within this region is as extensive as the area covered by the Illinoian ice-sheet. Its extent is shown on Pls. I and II.

Character of the Drift.—The Illinoian drift in this region consists of gravelly clay (Pl. 10, B.) characterized by a large percentage of chert and dolomitic limestone pebbles. Many of the chert pebbles are angular, as if not subjected to long wear beneath the ice. In its large percentage of chert and limestone pebbles, it differs from the Kansan drift. Its color is usually reddish or reddish-brown, but it is sometimes yellow. Leaching and weathering have not extended so deep as in the Kansan drift. The usual thickness of the Illinoian drift is 30 to 50 feet, but some records of a much greater thickness were obtained.

The drift is overlain by loess, which generally conceals it. Exposures may occur in deep road cuts, in gullies, and on steep valley slopes where the loess has been eroded away.

The Topography of the Illinoian Drift-Plain.—When the Illinoian ice-sheet melted, it left a plain of slight relief except that the larger valleys remained unfilled. Many of the smaller valleys were probably completely filled by the Illinoian drift. On the uplands farthest away from the main drainage lines, remnants of this plain still remain much as the ice left it. This is the case northwest of Davenport, east of Mt. Carroll, and in places on the Garden Plain, Coe, and Moline uplands. But most of the Illinoian plain within this region is now dissected by valleys, whose development has been favored by the existence of the large valleys of the region, which the drift did not fill. The relief of the dissected part of the Illinoian drift-plain is from 50 to 100 feet. The less advanced erosion of the Illinoian drift, and the undissected remnants of the original plain distinguish this area from the Kansan drift-plain.

THE SANGAMON INTER-GLACIAL EPOCH.

The inter-glacial epoch following withdrawal of the Illinoian ice-sheet is known as the *Sangamon epoch.* Erosion was in progress during this interval, and the more advanced erosion of the Illinoian drift surface as compared with that of the Iowan, gives some suggestion of the duration of the Sangamon epoch.

THE IOWAN GLACIAL EPOCH.

The ice-sheet of this epoch is called the Iowan, because the drift it left is best known in Iowa. The ice which reached this region in this epoch was the eastern extension of a large sheet farther west, and this in turn was a part of the great northern ice-sheet of that time.

Area Covered.—The Iowan ice-sheet entered this region from the west and advanced eastward along the Wapsipinicon valley. The probable area covered at the time of its maximum extension is shown in Fig. 16, which is based upon the maps of the Iowa Geological Survey.[1]

Area of Exposed Iowan Drift.—No part of the area covered by the Iowan ice-sheet within this region was afterward glaciated. The Iowan drift-plain is therefore, the same as the area of the Iowan ice-sheet in

1 "Maps of the Superficial Deposits of Scott County," Norton, Iowa Geol. Surv., Vol. IX, p. 492. Clinton county, Udden. Vol. XV, p. 416.

this region. In this statement and in the corresponding statement with regard to the Kansan and Illinoian drift-plains, the areas now covered by the alluvial flats of the great valleys and by the sand dunes, are left out of consideration. The extent of the Iowan drift-plain is shown on Pl. I.

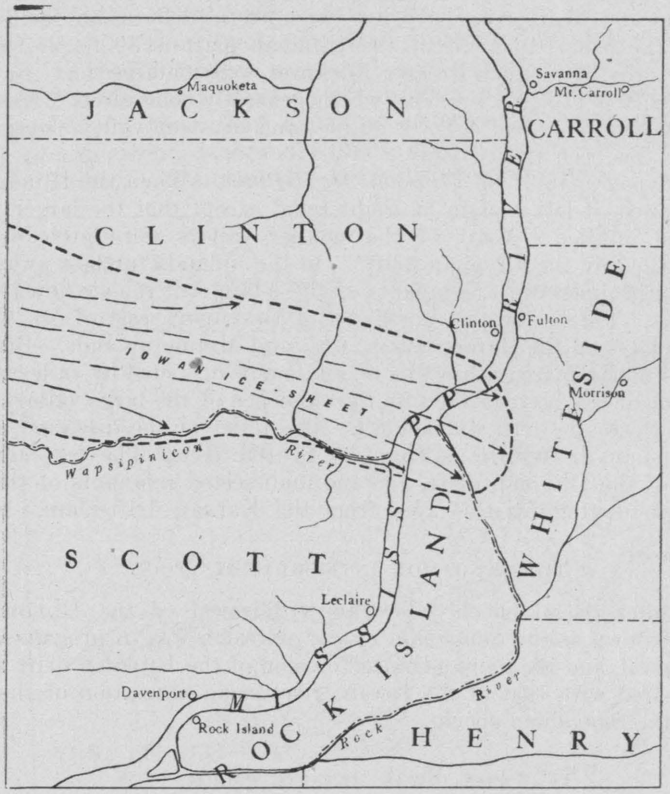


FIG. 16. Sketch map of this region showing the probable maximum extension of the Iowan ice-sheet.

Character of the Drift.—The Iowan drift of this region is more sandy, and has a larger proportion of pebbles, cobbles and bowlders, than either the Kansan or the Illinoian drift. This shows in the till and also in the associated deposits of stratified drift. The color of the drift is yellow, similar to the Kansan. Because of the slight development of the loess over the Iowan drift, it appears at the surface much more frequently than do the other drifts. Road cuts are few, for the topography is relatively even, but such cuts as occur and the shallow valleys show frequent exposures of the stony drift. The Iowan drift is seldom leached of its lime carbonate to a depth of more than a foot or so, and where the loess occurs it may be calcareous up to the base of the loess. The drift of this age is thin, usually forming only a thin veneer of 5 to 10 feet. Thicker deposits of quicksand and beds of gravel occur frequently in the drift, and some of them probably mark the courses of valleys on the surface of the Kansan drift which were filled with Iowan drift during the advance of the Iowan ice-sheet.

Loess laps up on the margin of the Iowan drift for several miles, and occurs in patches over all of the Iowan plain, but it does not form as complete a covering as over the Kansan and Illinoian drift sheets. At the margin of the Iowan drift, where the loess is continuous with that of the adjoining region, the loess often has a thickness of 10 to 15 feet; but over much of the plain the thickness is but 2 to 4 feet, or it may be entirely absent. Sand areas are numerous on the Iowan plain, usually extending in a west-northwest to east-southeast direction. The sand is usually covered with grass sufficient for pasturage. The more level uplands and the swampy areas have a black humus soil 6 to 12 inches, or rarely a few feet in thickness. It is thickest where the land is flattest and absent where the slopes are such as to have allowed much erosion.

Bowlders.—Over the Iowan plain, bowlders are frequent and in some places numerous. They are of igneous rocks (coarse grained granites and dolerites), and are usually 1 to 3 feet in diameter, but sometimes much larger. Two miles south of Low Moor, Clinton county, Iowa, in the S. E. quarter of Sec. 34, and N. E. quarter of Sec. 3, is an area where surface bowlders abound. In clearing the land for farming, the bowlders are usually removed and piled along the fences, or if too large to be moved easily, are buried by digging pits at the sides, and allowing them to fall in, the burial being deep enough so that the plow may pass over them. It is frequently reported that bowlders appear again after a few years in fields from which they have been removed or buried; that is, the bowlders are thought to work upward. On slopes this may be partly due to erosion which by lowering the surface exposes the bowlders; but the phenomenon is most common on level swampy uplands. The raising of the bowlders is similar to the raising of fence posts in wet lands in winter, a phenomenon well known to many farmers. Ice occupies more space than the water from which it was formed, as shown by the bursting of vessels in which water freezes. When the ground (really the water in the ground) freezes, and the water in the pores of the soil becomes ice and expands, the bowlder is pressed upon from all directions. If movement takes place as a result of this pressure, it will more probably be upward than in any other direction, because that is the direction of least resistance. The earth crowds in under the bowlder so that the latter does not settle back to its former position when the ice melts. Although this movement must be very small at any one freezing, it may be that in course of time such small movements are sufficient to force the bowlder up nearer to the surface. Figure 17 is a diagram to illustrate the suggested explanation. With this explanation it is evident that the phenomenon would be most prominent in wet places where the ground is saturated, and where the change from water to ice takes place oftenest. If the burial of a bowlder is to be permanent, most of it must be sunk below the depth to which the ground water freezes.

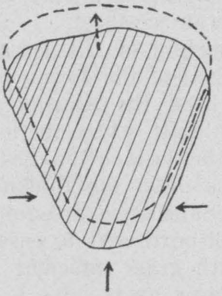
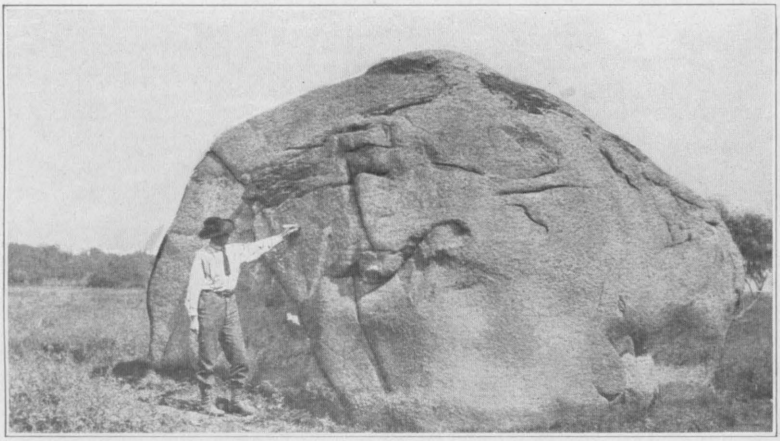


FIG. 17. Diagram to illustrate a possible explanation of the phenomenon of rising bowlders. The bowlder is pressed upon from all sides by the frozen earth. This may crowd it up to the position shown by the dotted outline.

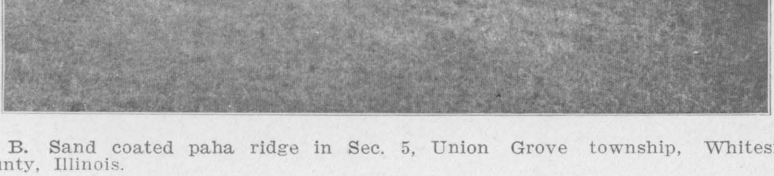
In the abandoned valley east of Albany, Whiteside county, Illinois, the valley bottom is strewn with bowlders, and some occur well up the slopes toward Albany. Bowlders 2 to 6 feet in diameter are very common, and some are much larger. They consist of very coarse grained red and gray granites, and dark colored igneous rocks, and look much like the bowlders of the Iowan region west of the Mississippi. One of these lying on the bottom of the channel south of the road running east from Albany is a rectangular block of reddish-gray granite 18 feet long, 15 feet wide and 12 feet high (Pl. 11, A.) At a distance, this bowlder looks very much like a hay stack, and is reported to have been sold as such several times at bargain prices. The volume of the exposed part of the bowlder is about 3,200 cubit feet, which, with a specific gravity of 2.65 would give it a weight of about 268 tons.

The Topography of the Iowan Drift-Plain.—The topography of the Iowan plain is the smoothest of the upland areas. Much of it is essentially as the ice-sheet left it. Parts of it are so flat that ponds and swamps exist during wet seasons in many places. Good examples of this even topography are found around Low Moor, Clinton county, Iowa. North and east of this place a swamp formerly covered an area of several square miles, but most of it has been drained by tiling and ditching, and now forms excellent farming land. South of Low Moor, swamps and ponds 10 to 20 acres in extent frequently occupy shallow depressions in the upland.

The drainage of the more level portions of the Iowan plain is through depressions which existed when the ice retreated. Their courses may be very irregular, and the gradients so low that the water creeps along through swampy tracts rather than flows as a stream. Where the gradient is a little greater, the stream cuts a shallow channel along the middle of the depression, and this channel drains the level portion on either side, which earlier may have been swampy. This is the condition of the former swamp area east of Low Moor.



A. Glacial bowlder on the bottom of the abandoned channel east of Albany, Illinois.



B. Sand coated paha ridge in Sec. 5, Union Grove township, Whiteside county, Illinois.

The drainage of the Iowan drift-plain is very youthful. It is the drainage of an upland plain of slight relief, where valleys have not yet advanced far in their development. Around its margins adjacent to the Mississippi and Wapsipinicon lowlands, the Iowan plain has been cut into by many small valleys. These started as gullies on the steep slope separating the lowland and the upland, and are working headward into the upland plain. In time these valleys and their tributaries will extend to every part of the Iowan plain, and dissect it to the more advanced stages shown in the Illinoian and Kansan drift-plain.

The general elevation of the Iowan plain is 680 to 700 feet, being 40 to 80 feet lower than the Kansan to the north, and the Illinoian on the south side of the Wapsipinicon (Fig. 18). To the north, the Iowan plain becomes more rugged as it approaches the Kansan plain, and for a distance of 3 to 4 miles from the boundary, is quite well dissected. There is a considerable slope from the Kansan plain down to the Iowan, and on the south the latter slopes gently off to the Wapsipinicon bottoms (Fig. 18).

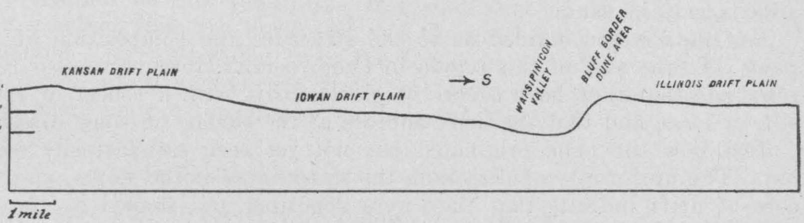


FIG. 18. Generalized surface profile showing the relation of the Iowan drift-plain to the Kansan to the north, and the Illinoian to the south.

The Paha.—The surface features of the Iowan plain include besides those of erosion, long low swells and shallow depressions which have a west-northwest to east-southeast direction. These may be merely slight flutings or irregular lenticular elevations; but in some places they are elongated hills or ridges with well rounded contours and even slopes (Pl. 11, B). These hills, called *paha* by McGee,[1] are characteristic of this part of the Iowan plain. They have their best development to the west and northwest in Iowa.[2] A few scattered paha are found in southern Clinton county. They occur in isolated elongate hills, or as a series of hills joined end to end. They rise 5 to 40 feet above the plain, and range in length from a fraction of a mile to several miles, with an average of about a mile. The usual width is about a fourth of a mile, but this varies greatly. The side slopes are convex.

There is a good example of a paha near the east end of the Iowan plain in the N. ½ of Sec. 31, T. 81 N., R. 6 E., 3 miles west of Camanche. The hill has the usual west-northwest to east-southeast direction, an elevation of 20 to 30 feet, and a length of almost a mile. The

1 McGee. U. S. Geol. Surv., Eleventh Ann. Rept., Pt. I, p. 220.
2 Norton. Iowa Geol. Surv., Vol. XI, 1900, pp. 356-366.

surface material is sandy loess down to a depth of 18 inches. Below this, fine sand extends to a depth of at least 3 feet. Mr. Willett, who lives at the west end of this ridge, struck rock in his well at 10 to 18 feet, the material immediately overlying the rock being blue clay.

Further west on the Iowan plain, paha ridges are more numerous. In T. 81 N., R. 5 E., southwest of Elvira, a long narrow paha ridge extends from the middle of Sec. 6, in an east-southeast direction through Secs. 5 and 8 to the Goose Lake channel. On the east side of the channel the ridge continues through Secs. 9 and 10, making a total length of more than 3 miles. It encroaches upon the Goose Lake channel from either side, and has evidently been cut across by Brophy creek. The ridge consists of a number of elongate hills joined end to end. West of Brophy creek, the surface of the ridge is very sandy, and the hills on its crest are largely of wind driven sand. Fine sand is exposed in the east bank of the creek where it cuts the ridge. Farther east its surface is overlain by loess and black soil. Exposures in the road cut on the south line of Sec. 5, and well records, indicate that this paha ridge consists largely of sand.

Few data were obtained as to the structure and composition of the paha. To the west of this region in Cedar county, Iowa, Professor Norton finds that they have a core of glacial drift with a veneer of sand, silt, or loess, and that the drift appears at the surface in some cases.[1]

Just how the paha originated has not yet been satisfactorily made out. The uniformity of direction, the smoothness of the slopes, and the core of drift indicate that they were deposited and shaped by the ice which over-rode the region; but as a few are known to occur beyond the Iowan drift area, out on the Kansan, their connection with a particular ice-sheet is not clear. The sand and silt covering the paha, or according to the account of McGee making the paha, were thought by him to be the deposits of streams flowing beneath the ice, or in ice-bound channels cut through the ice near its margin. The surface sand and silt of the paha have been reworked by the wind in many cases, and piled up into mounds of sand on the crests of the paha ridges.

The Iowan-Like Area Southwest of Morrison.—At about the same time that the Iowan ice-sheet from the northwest invaded this region, an ice-sheet advancing from the northeast across northern Illinois, reached to eastern Whiteside county. It was really a part of the same ice-sheet for both were marginal lobes of the great ice-sheet to the north. Between the areas which can be referred positively to the ice which moved in from the northwest or the northeast, there is an area of drift with Iowan-like topography, south and southwest of Morrison. Part of this area is shown in the eastern part of the Cordova map, east of the Cattail valley in Union Grove township, Whiteside county. On Pl. I this area is not separated from the Illinoian drift-plain. The topography of this area is more even than that of the Garden Plain upland west of the Cattail valley, or the region north of Union Grove township. Much

1 Norton. Iowa Geol. Surv., Vol. XI, p. 360.

of the surface has been but slightly affected by erosion, and is characterized by lenticular hills and ridges having a west-northwest to east-southeast direction, like the paha ridges of the Iowan plain west of the Mississippi. These paha ridges are prominent for several miles east of the Cattail slough, and occur south and southeast of Morrison. Good examples may be seen in Secs. 4, 5, 8, and 9 of Union Grove township. One of them in shown in Pl. 11, B.

At the north end of Cattail slough, west of Union Grove, the bluff is bordered by a belt of dunes the sand of which is still shifting. East of this in the sections west and southwest of Union Grove, the paha ridges are largely of fine sand, and the intervening spaces are coated with sandy loess. Farther southeast, the sand gives place to sandy loess, but the typical fine grained loess is rarely found. Bowlders are reported to appear in the fields 3 to 4 miles southeast of Morrison, and a few were seen near Union Grove. Drift exposures are few because of the evenness of the topography, rather than because of the thickness of the loess, but where seen it is composed of yellow gravelly clay.

The relation of this Iowan-like area southwest of Morrison to the Iowan ice-sheet from the northwest and the northeast has not yet been determined. It is separated from the Iowan areas on the west by the high Garden Plain upland, and from the Iowan area on the east by an area of more mature topography southeast of Morrison.

THE PEORIAN INTERGLACIAL EPOCH.

The Iowan glacial epoch was followed by the *Peorian interglacial epoch*. But as no later ice-sheets entered this region, the erosion of this interglacial epoch cannot be distinguished from that of later time. For all of this region, except the valley bottoms, erosion has been continuous since the withdrawal of the Iowan ice-sheet.

THE WISCONSIN GLACIAL EPOCH.

The ice-sheets of the Wisconsin epoch did not reach this region, but indirectly they produced effects of considerable importance.

Deposition in the Main Valleys.—With the advance of the Wisconsin ice-sheet over the upper parts of the basins of the Mississippi and Rock rivers, these streams received the floods from the melting ice, and carried them across this region. When the waters left the ice front, they were heavily loaded with gravel, sand, and silt, much of which was deposited near the margin of the ice. But a considerable quantity of this debris was carried down the valleys. With a gradually decreasing gradient, the streams dropped a portion of their load. Gravel and sand were deposited in the channels of the streams and raised them to the levels of the flood-plains, and then the streams wound about on these plains.

When the valley followed by the Mississippi was built up (aggraded) to the level of one of the abandoned channels of the region (such as the Cattail or Meredosia channels), both courses were followed by the water at the same time, or at successive times and both were built up. This aggradation continued until the valley floor was raised to the level now represented by the second bottoms or terraces, about 620 feet above sea-level and about 40 feet above the Mississippi.

Part of the valley plain built up at this time has been lowered since by the erosion of the river. The part which has been brought low forms the *flood-plains*, and other low-lying lands of the valley. That part of the original plain which remains, forms the *second bottoms* or *terraces*. The boundary between the two divisions is not always distinct, but in general the flood-plains are the low lands bordering the rivers, and covered by water in times of flood, while the terraces are those level plains in the valleys which are above the reach of floods.

The division of the lowlands into flood-plains and terraces is the result of erosion which has taken place since the glacial period and the features developed by this erosion might be described in a later chapter, but the deposits which make the terraces, and underlie the flood-plains were laid down in the Wisconsin glacial epoch, and the flood-plains and terraces will be described here along with the description of these deposits.

The Terraces or Second Bottoms.

The More Important Areas of Second Bottoms.—The areas of second bottoms are shown on the accompanying maps (Pls. I and II). They occur in the broader parts of the Mississippi and tributary valleys. The largest area of this sort occurs on the Illinois side of the river between the Garden Plain upland on the south, and the narrowing of the valley at Savanna on the north. This area is about 15 miles long, and 2 to 4 miles wide. A second large area of second bottoms occurs in Cordova township in the north end of Rock Island county, between the Mississippi on the west and the channel of the Meredosia slough on the east. On the Iowa side, a small area of the same sort is found in a re-entrant in the bluff just south of Elk River Junction, and from Clinton south to the mouth of the Wapsipinicon, most of the area between the river and the bluff is above the level of flood waters. Many other small areas in the Mississippi valley belong to this division as may be seen from the map. Areas of second bottoms occur on both sides of the Wapsipinicon, and at its mouth they join with those of the Mississippi valley. Small portions of Rock river and Meredosia bottoms northwest of Erie are well above flood waters, but the larger part is low and swampy.

General Characteristics.—The second bottoms usually lie between the flood-plains on the one hand and the valley bluffs on the other, as shown diagramatically in Fig. 2, p. 3. Where the valleys are narrow, as the Mississippi valley below Princeton and Cordova, the second bottoms are absent, or represented by very narrow benches (terraces) only. Where the valleys are broad, as the Mississippi valley above Clinton, the second bottoms may attain considerable width. They may occur on one or both sides of the river, and if present on both sides, they are usually of un-

A. Exposure of sand and gravel, in the bank of the Mississippi river, just south of Hampton, Rock Island county, Illinois.

B. Cordova Flats. Rock Island county, Illinois.

equal width. In this region, the second bottoms of the main river valleys are continuous with level plains in the valleys, such as the Cattail and Meredosia valleys, through which no streams now flow.

The elevation of the terraces of the Mississippi valley commonly ranges from 590 to 610 feet above sea-level, and about 40 feet above the stream. They are highest north of Savanna at the mouth of Rush creek, where the terrace has an elevation of more than 620 feet. To the south the terrace level declines at about the same rate as the river. The terraces rise gradually toward the bluffs and grade into the talus slopes without sharp demarcation (Fig. 2). Toward the river the terraces descend, sometimes abruptly, sometimes gradually, to the flood-plain level about 20 feet below. From Cordova to the upper end of the Meredosia slough, the flood-plain is absent, and the terrace plain fronts the river directly, and rises 35 to 50 feet above it.

The surface of the second bottoms is usually rather flat (Pl. 12, B.) but the flatness is interrupted locally by slight depressions and elevations. The depressions are broad and shallow, generally elongate in the direction of the valley. Some of them are occupied by swamps and shallow lakes.

On the line between Carroll and Whiteside counties two miles south of the village of Thomson is a swamp and lake which formerly covered an area of several square miles (Pl., I.) It is fed by Johnson creek from the northeast. A drainage ditch has recently been cut from the swamp south to Otter creek, and a considerable part of the swamp has been reclaimed. Another large swamp extends from the north line of Sec. 18, York township, Carroll county, north along the bluff through Dyson and Idens lakes to the sharp bend of Plum river, where that stream leaves the bluff southeast of Savanna. This area is 10 to 15 feet lower than the plain to the west, and on the east it extends to the base of the talus slope of the bluff. It is almost a mile in width, and more than five miles long. Dyson, Idens and several smaller lakes are permanent bodies of water in this swamp. Plum river used to flow into this swamp in times of flood from its bend in Sec. 13, Savanna township, but a dam across the northern end of the swamp now prevents this.

The most conspicuous elevations on the second bottoms are the sand dunes. Where they occur, as at Ebner north of Fulton, and east of Cordova, the topography is uneven, and the elevation usually higher than that of the surroundings.

The soil of the second bottoms is usually black and sandy, but it grades to humus soil in the swamps, and to nearly pure sand in the dune areas. In all places, however, sand or gravel is found at the depth of a few feet. On the whole the second bottoms form one of the most fertile areas of the region. Their rich loose soils are well adapted to the cultivation of potatoes, and this is one of the chief crops of the area. Corn is also extensively grown upon them. The more sandy portions, as around Thomson and farther north, yield large crops of melons.

The Flood-Plains.

The Important Flood-Plains.—The areas of flood-plains are shown on the accompanying maps (Pl. I and II). The most extensive are in the Mississippi valley between Savanna and Clinton, along the Meredosia slough, and in the Rock and Wapsipinicon valleys.

The flood-plain between Savanna and Fulton is one to two miles wide, and is separated from the second bottoms which occupy the east part of the valley, by an abrupt rise of 10 to 20 feet. Near the river, the flood-plain includes numerous bayous which cut off long strips of land from the mainland and form islands accessible during only a part of the year. A marshy tract lies east of Fulton island, and at flood times water passes through this swamp to Cattail creek, and joins the Mississippi two miles to the southwest.

Starting from the upper end of the Meredosia slough just south of Albany, a belt of swamp land runs south-southeast around the northeast corner of the Coe upland to the Rock river just east of Hillsdale. To the east of this belt of swamp land, in Erie, Newton and Fenton townships of Whiteside county, there is a large tract of land really above the reach of the floods, but it possesses the characteristics of the flood-plains, rather than those of the second bottoms, and is therefore mapped with the former (Pl. I).

General Characteristics.—The flood-plains rise 15 to 20 feet above the river level at ordinary stages of the stream. Their surfaces are often marked by broad shallow channel-like depressions, followed by the flood waters. Near the main channel these depressions may contain water most of the time, and from a network of bayous with intervening areas of swampy timbered land. Swamps and ponds are numerous over most of the flood-plain areas. In wet seasons they are covered with water, but in dry seasons they are accessible for pasturage.

The surface material of the floodplains is an alluvial soil, usually black and rich in humus. It has a thickness of 5 to 15 feet. In the Mississippi valley above the Narrows, and in the Meredosia valley, this soil rests on sand, while in the Mississippi valley below the head of the Narrows, and in the Rock River valley, it rests on a rock-floor. Where the slope is sufficient to drain the land, the flood-plains form good farming land. The soil is more compact than that of the second bottoms, and corn is the chief crop of the area.

A large tract of land at the union of the Meredosia and Rock River valleys, in Newton and Erie townships of Whiteside county was formerly so swampy as to be of little value. But much of it has been drained by ditches, and is now valuable farming land. The surface material is a mucky blue to black soil, two to three feet thick, overlying a yellow sandy deposit. The black surface material is sometimes of a peaty nature.

The Material of the Lowlands.

Below the thin soil horizon of the second bottoms and of most of the flood-plains, occurs the sand and gravel deposits of the Wisconsin glacial epoch. These materials are exposed in a number of cuts in the region, and are penetrated by the wells of the lowlands. The material is very

A. Pebbles of one of the gravel layers shown in Pl. 10, A.

B. Cross bedded sand in a pit of the C., R. I. & P. Ry. Co., a mile southwest of Rock Island.

loose, and driven wells are the rule on the broad flat north of Fulton. At many places on this flat between Thomson and Fulton, a layer of clay about a foot thick is reported to exist at a depth of 4 to 10 feet. It is nearest the surface on the lower parts of the flat, and farther down where the surface rises. Below the clay, sand and fine gravel go down as far as the wells have penetrated.

Exposures showing the structure of the sand, were found only in artificial excavations, usually in fresh sand and gravel pits. The sand is fine-to-medium grained, with occasional layers of coarse sand and gravel. It is stratified and cross bedded. The thicker layers are essentially horizontal, but layers often thicken or thin laterally, or pinch out entirely. The laminæ of the main layers may be inclined at any angle up to 20° to 30°, but they nearly all dip down stream (Pl. 13, B). The laminæ vary in thickness and composition. Those containing some clay are more or less impervious to water, and when moist, stand out on the face of the pit.

A mile southwest of Elk River Junction, about 10 miles north of Clinton, near the north line of Sec. 31, Elk River township, the C. & N. W. Ry. Co. has opened a large sand pit, in the edge of the terrace. The upper 15 to 20 feet consists of fine-to-medium grained cross bedded sand, which rests on fine gravel, made up largely of dark colored pebbles. A well at the farm house just north of the pit, goes 65 feet in sand and gravel, and stops in coarse gravel. A detailed section of a portion of this sand pit, as seen on one of the visits to it will serve to illustrate the general characteristics of this and all other exposures of valley deposits seen in this region.

Section of the bank of a sand pit of the C. & N. W. Ry. Co. a mile southwest of Elk River Junction. Number 1 is at the bottom and number 12 at the top:

12.	Sand, passing up into soil; does not show structure		4 feet
11.	Steeply inclined laminæ of coarse and fine sand		12 inches
10.	Horizontally bedded fine sand, containing layers of coarse sand		18 inches
9.	Inclined, alternating layers of coarse and fine sand		2 feet
8.	Alternating layers of pure sand and more or less clayey sand.		6 inches
	(5) Impervious sand	1 in.	
	(4) Fine grained sand	3 in.	
	(3) Impervious sand	1 in.	
	(2) Coarse sand	1 in.	
	(1) Impervious sand	½ in.	
7.	Coarse sand; highly inclined yellow and black laminæ		6 inches
6.	Horizontally bedded sand, some layers of which are relatively impervious to water		3 inches
5.	Inclined laminæ of fine grained sand; laminæ differ in size of grain, porosity, induration and resistance		8 inches
4.	Fine grained sand; so moist that bedding is barely distinguishable		6 inches
3.	Silty sand; compact and impervious		1 inch
2.	Slightly inclined layers of medium grained sand, with thin, relatively resistant layers in which the sand grains cohere, and thicker layers of loose grains. Resistant layers stand out on the surface		15 inches
1.	Talus slops extending to the base of the pit	6 to	8 feet

Very coarse sand and gravel is exposed in a 15 foot bank at the edge of the river, just south of the village of Hampton, Rock Island county, Illinois (Pl. 12 A). At the base there is gravel, some beds of which are 2 feet thick, interbedded with thinner layers of coarse sand. The pebbles of the gravel layers range up to 2 inches in diameter, but a large percentage of them fall between 1/4 and 1/2 inch in diameter (Pl. 13A). They are almost wholly of igneous rock, only one limestone pebble being found in 100 taken at random from the bank. The gravel becomes less abundant toward the top and the uppermost 4 feet of the bank is of fine sand, with only an occasional pebble.

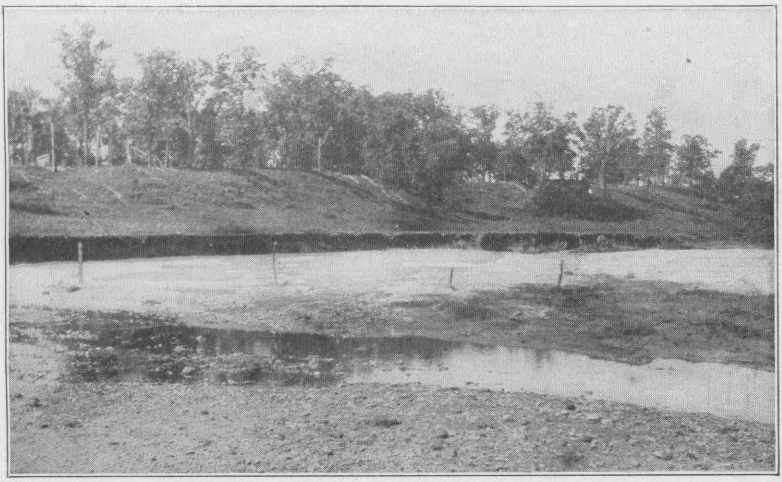
Other good exposures, showing the structure of the valley deposits, were seen in a sand and gravel pit in the west part of Lyons, in a pit of the C., M. & St. P. Ry. Co. in the terrace front just south of the Wapsipinicon river near the south line of Sec. 23, Princeton township, in a pit of the C., B. & Q. Ry. Co. south of their tracks 2 miles east of East Moline, and in a pit of the C., R. I. & P. Ry. Co. (Peoria Branch) about a mile south of the west end of the city of Rock Island (Pl. 13 B). Less perfect exposures occur in many places throughout the region, and may be looked for wherever an excavation cuts the valley flat. From the exposures seen the valley deposits appear to consist of coarser material in the northern portion of the region, than in the southern.

The thickness of the sand and gravel deposits of the valleys varies with the unevenness of the rock-floor below. Data are wanting concerning much of the region, and other portions are known only in the most general way. North of Fulton, on the broad valley flat of the Illinois side, the wells are all shallow, the deepest being the town well at Thomson, which has a depth of 37 feet, all in sand and fine gravel. The deep well at Sabula passes through 165 feet of alluvial filling before striking rock. The well at Fulton reaches rock at about 200 feet, and a boring at the Clinton brewery between Clinton and Lyons is said to have passed through 287 feet of sand and gravel, and to have stopped without reaching rock. A well in the northwest part of Camache penetrates 73 feet of sand and gravel. Two wells in Secs. 8 and 17 of Cordova township, Rock Island county, strike rock at a depth of about 100 feet. Farther east on the Meredosia bottoms toward Erie no well records of more than 40 feet were obtained. The surface material of the Wapsipinicon bottoms is frequently a black loam, or a sticky gumbo clay, but these materials are no more than a few feet thick and beneath them sand and gravel extend to below the bottoms of the deepest wells, which are, however, only 35 to 40 feet deep.

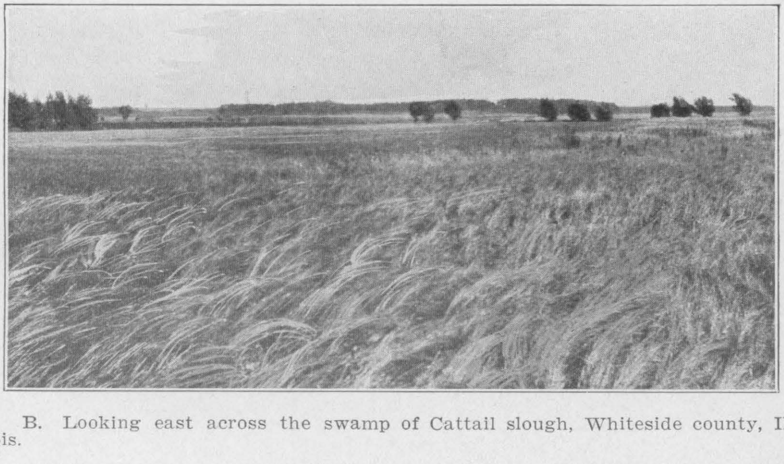
No sand or gravel deposit is present in the Mississippi valley below the head of the Narrows or in the Rock River valley. The rock-floor is reached below a few feet of soil and river alluvium.

DEPOSITION IN THE SIDE VALLEYS.

While the main valleys were being aggraded by the flood waters of the Wisconsin glacial epoch, the lower courses of the tributaries were obstructed by the filling of the main valleys to which they flowed. This



A. Terrace front on the south side of the valley in Sec. 20, Mt. Carroll township, Carroll county, Illinois.



B. Looking east across the swamp of Cattail slough, Whiteside county, Illinois.

made the tributaries slack in their lower courses, and the sediment brought in by them was deposited in these slack water tracts. Flats were thus built up in the lower courses of the tributaries corresponding in elevation to that of the main valley. The material was local to the tributary's drainage basin, and consisted largely of fine silt and clay from the drift and loess of the upland. Deposited in the lower parts of the side valleys, it formed a laminated clay deposit.

Since the time of maximum valley filling of the Wisconsin glacial epoch, the filling of the side valleys has been partly removed by the streams. Those parts of the original flats which remain, now constitute terraces in the sides of the valleys. The pricipal terraces of this sort are shown on the accompanying maps (Pls. I and II), and will be referred to in the succeeding paragraphs. In mapping the terraces of the side valleys all areas showing the characteristic terrace deposits were included even though the terrace form is not shown.

General Characteristics of the Side Valley Terraces.—The terraces are best developed just above the union of the small valleys with the Mississippi. They become less prominent farther up the valleys and are seldom distinct more than 2 miles from the Mississippi bluffs. The terrace areas are small and patchy, and seldom continuous for more than a fraction of a mile. They rise 20 to 40 feet above the creeks, and at the mouths of the valleys they seem to be continuous, topographically, with the terraces of the main valleys. The rise of the terraces up stream is slightly less than that of the stream bed, so that they become lower, relative to the stream, as the valley is ascended, and finally grade into flood-plains.

Along the north branch of Mill Creek, Clinton township, about 2 miles west of the city of Clinton (Pl. I), in W. ½ of Sec. 11, a good terrace occurs on the west side of the valley about 25 feet above the flood-plain of the creek and nearly 40 feet above the stream bed. It has in some places a width of 30 to 40 rods and continues along the valley for more than half a mile. Farther up the creek other smaller patches of terrace occur at intervals for a couple of miles.

A good terrace borders a small creek which joins Otter creek from the north, near its mouth. This creek flows south through Secs. 4, 9, and 8 of Ustick township, Whiteside county, Illinois, parallel to and about a mile east of the Mississippi bluff (Pl. I). For more than a mile up this creek a steep terrace slope of 15 to 25 feet fronts the channel of the stream, though the terrace flat above is narrow. Terraces occur along the lower course of Plum river northeast of Savanna (Pl. II), along Elk river in the S. ½ of Sec. 18, Elk River township, Clinton county, Iowa (Pl. I), in a small valley 3 miles north of Lyons, and in small patches in many other tributary valleys (Pl. 14, A).

The Constitution of the Side Valley Terraces.—The material of the terraces of the side valleys is of two classes, a blue or drab clay below, and a horizon of variously colored laminated clays and sands above. The first appears in only a few of the deeper exposures along the creek banks. It contains considerable organic matter, and often has a mucky odor as if it contained decaying organic matter. In a few cases thin layers of sandy clay occur near its top; but usually the material continues unchanged until sharply overlain by the laminated clays and sands above. The lower clay is sometimes horizontally bedded, but usually the layers are undulating or contorted. Iron staining occurs along the bedding plains, and ferruginous concretions of the general form of pipe stems are often present.

Exposures of the upper member are much more frequent, because it overlies and extends beyond the lower division. The material ranges from sticky gumbo, through all grades of sandy clay, to sand, and layers and lenses of gravel occur in some exposures. The clays consist of variously colored laminæ, red, brown, blue, gray, yellow, and intermediate colors, and are often embedded with colored sandy layers. The upper part of the exposure is usually brick red or reddish-brown clay, while the lower layers show a greater range of colors. The laminæ are sometimes horizontal, but more often inclined and contored. At the surface the material becomes a sticky gumbo clay, and this is sometimes the only indication seen of the terrace deposits.

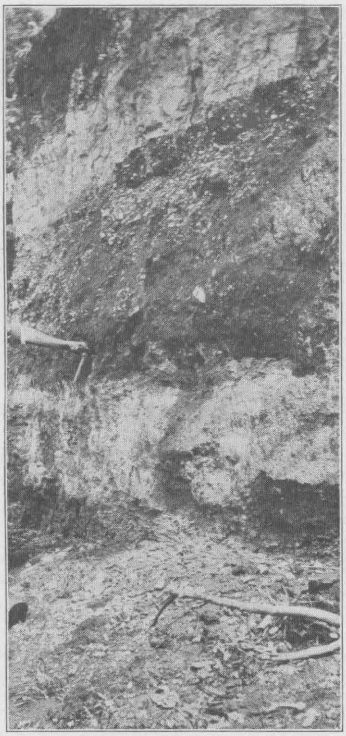
A characteristic section occurs in the west bank of the north branch of Mill Creek, S. ½, N. W. ¼ of Sec. 11, Clinton township, Clinton county, Iowa. The section is as follows, number 1 being at the botom:

6.	Laminated clays; yellow, brown, red, gray, blue, etc., with layers of sandy clay	12 feet
5.	White silty clay	2 feet
4.	Gravel lenses; the gravel is coarse, some pebbles being 3 to 4 inches in diameter	6 to 12 inches
3.	White to yellow stained silty clays. Contact with pebbles above is iron stained	1 foot
2.	Gravel and sand; cross bedded, with seams of white silty clay which are laminated and contorted	3 feet
1.	Compact, blue, mucky clay	8 feet

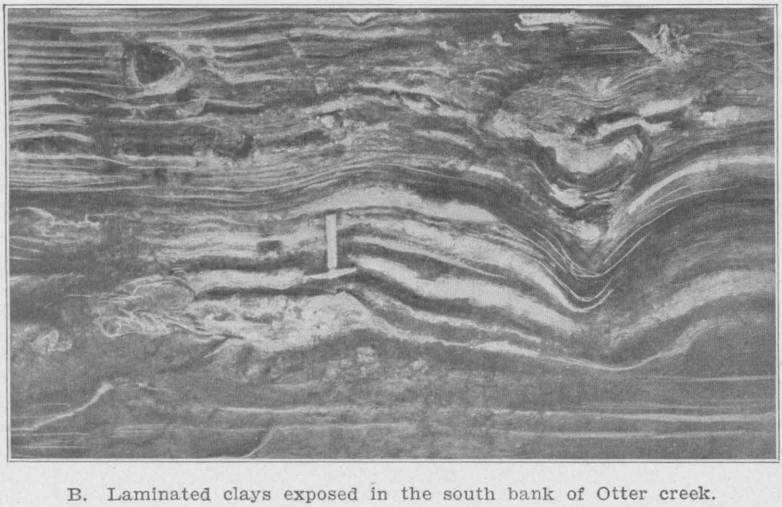
Other exposures of laminated clays may be found along Otter creek (Pl. 15, B), Spring brook, Elk river, and in many other side valleys, throughout the region. Near the mouth of Duck creek in the N. W. ¼ of Sec. 27, Pleasant Valley township, 4 miles east of Davenport, the blue clay is absent, and the laminated clays rest directly upon a gravel deposit (Pl. 15, A).

There is great uniformity in the side valley deposits wherever they are exposed throughout the region, and the characteristics are the same far south of this region. Their bright colors, thin layers and frequent alternation of layers and colors, make them easy to recognize.

Small gastropod shells were found in the laminated clays exposed in the south bank of Otter creek, a fourth of a mile above the mouth of the valley. No other outcrop examined yielded fossils. No fossils were found in the blue clay of this region, but in Calhoun county, Illinois, in side valley deposits apparently identical with those of this region, thin seams or layers in the blue clay contain material in abundance, such as sticks, leaves and gastropod shells.



A. Exposure in the south bank of Duck creek. The base of the bluff *a* consists of Coal Measures shales and sandstone, the middle *b* of glacial drift, the top *c* of laminated clays.



B. Laminated clays exposed in the south bank of Otter creek.

Just north of the stone quarry in the north part of Leclaire, excavations have exposed a zone of sticky red clay, about six feet thick, which rests upon glacial drift. Farther north in the cuts of the I. & I. Electric Ry. the bed-rock is overlain by this red clay, which in several exposures is seen to pass vertically or horizontally into a loess-like clay. It is not so thinly bedded or so variously colored as those of the side valleys, but it is probably related to them. A bench in the side of the valley in Davenport is said to be underlain by red clay which is probably like that at Leclaire, but no exposures were seen.

In the early stages of the filling, or probably before the Wisconsin epoch, the blue mud was deposited. At a later stage, most probably contemporaneous with the Wisconsin filling of the Mississippi valley, the variously colored laminated clays were laid down. In an exposure on Otter creek, the laminated clays appear to extend up over the slope of a dune sand accumulation. Elsewhere in the area, and farther south, the clays pass upward into silty clays, and loess-like deposits. This is not considered an argument against their assignment to the Wisconsin epoch, for both loess and sand deposits preceded and followed the Wisconsin epoch. The presence of the red clays in the Narrows above Leclaire may mean that this course was at times so clogged that it became the site of slack water.

Contrast Between Glaciated and Unglaciated Areas.

The effects of glaciation are brought out by a comparison of the glaciated and unglaciated areas. They differ in (1) topography, (2) drainage and (3) mantle-rock.

TOPOGRAPHY.

In the driftless area the surface features have been completely determined by stream erosion. The region is thoroughly dissected and a very large part of the surface is in slopes.

The surface features of a newly exposed drift-sheet, on the other hand, are not the result of erosion. They consist of well rounded hills and broad shallow depressions. Valleys, gullies, and ravines are absent. The drift-sheets of this region have, however, been exposed to erosion for different periods of time, and have been more or less dissected. The Iowan drift-sheet of southern Clinton county has been only slightly modified, while the Kansan drift-sheet has been well dissected, and its topography is similar to that of the unglaciated area. On the whole the topography of the glaciated area is much less rugged than that of the unglaciated area. The relief also is less than in the unglaciated area.

The fantastically weathered columns and turrets which occur along the bluffs north of Savanna (Pls. 7, B and 8) are not found in the glaciated region. They probably were present along all the bluffs at the beginning of the Pleistocene period but they were destroyed by the ice-sheets.

DRAINAGE.

The driftless area is well drained. Valleys extend to every part of its surface. The drainage lines of a portion of the driftless area are shown in Fig. 19.

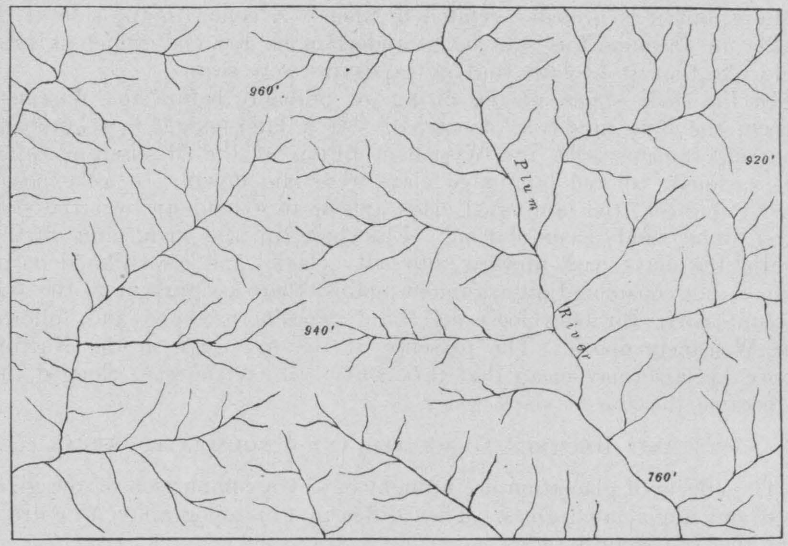


FIG. 19. Drainage of a portion of the driftless area northeast of Savanna. The numbers show approximate elevations above sea-level. Compare Fig. 20.

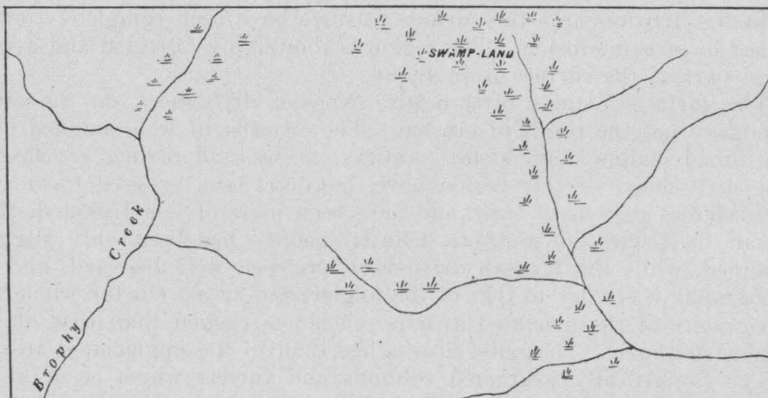


FIG. 20. Drainage of a portion of the Iowan drift-plain of southern Clinton county. Compare Fig. 19.

The drainage of a drift covered area is at first very irregular and there are very few streams. Marshes, ponds, and lakes are often abundant. Most of the drift covered area of this region, however, has become quite well drained and streams are more or less abundant. The drainage of a portion of the Iowan drift-plain is shown in Fig. 20.

MANTLE-ROCK.

The mantle-rock of the driftless area below the loess is local in origin, derived from the decay of the bed-rock below. It consists largely of the insoluable parts of the rock which have not been affected by weathering. It grades downward into the solid rock (Fig. 12).

The drift, on the other hand, is a variable mixture of local and foreign constituents, and of fine and coarse material. It was deposited in its present location by the ice-sheets. It contains both soluable and insoluable material. Its thickness is variable but usually much greater than the mantle-rock of the driftless area. The drift usually rests directly upon a definite rock surface which is often quite smooth (Fig. 14). The contrast of the contact of the drift with the bed-rock, and of the mantle-rock of the driftless area with the bed-rock is shown by comparing Figs. 12 and 14.

CHAPTER V.

CHANGES OF DRAINAGE.

In earlier parts of this report we have already described most of the large valleys of the region, but it may be well to summarize the matter here and add the description of a few other valleys before we attempt to discuss their relations to each other. The location of the valleys may be seen on the accompanying maps (Pls. I and II).

VALLEYS WITH STREAMS.

The Mississippi Valley.—North of the Narrows at Princeton the Mississippi valley has a width of three to seven miles and its bottom carries an alluvial deposit which extends to a depth of 100 to 200 feet below the river. Southward from the head of the Narrows, the river flows over a rock bed, and the bottom of the valley is but little wider than the stream itself.

The Rock River Valley.—Rock River valley has a width of three to five miles, and from a few miles below Erie to its mouth, it is known to be underlain, at a depth of a few feet, by a rock floor. At Barstow, the river makes a sharp turn to the south, flows through a narrower valley for a short distance, and then continues west in a line which is a continuation of the course of Green River valley (Fig. 1.)

The Wapsipinicon River Valley.—The Wapsipinicon River valley, three to four miles wide, enters the region from the west, and joins the Mississippi just north of the head of the Narrows. The bottom of its valley is filled with sand to a depth of at least 35 to 40 feet.

VALLEYS WITHOUT STREAMS.

One of the remarkable features of this region is the great valleys without streams. These valleys are shown on the Cordova map (Pl. I).

The Meredosia Valley.—Three valleys not now occupied by streams lead off from the Mississippi to the east, and extend to Rock River valley. The largest of these is the Meredosia valley, opposite the mouth of the Wapsipinicon. It is represented by the Cordova flats and the Meredosia bottoms, and joins the Rock River valley northwest of Erie. Its bottom is filled with sand to a depth of at least 100 feet.

The Cattail Valley.—The second streamless valley is the Cattail which, leaving the Mississippi southeast of Fulton, passes southeast and joins the Rock River valley south of Fenton Center. The floor of Cattail valley is mostly swampy (Pl. 14, B.), and much of it is covered with water during most of the year, and grows only rank swamp grasses. Toward its ends, it is better drained, and more of it is available for cultivation. The valley is underlain by peat which attains a maximum thickness of 25 to 30 feet on the divide between the creeks flowing to the north and to the south. Below the peat fine sand is found, but no record was obtained as to its thickness.

Pleasant Valley.—The third streamless valley connecting the Mississippi and Rock River valleys, is Pleasant valley, which leaves the Mississippi between East Moline and Watertown and extends east to the Rock River valley at Barstow. It is 20 to 30 feet above the rivers at either end, and its bottom is covered with 20 to 40 feet of sand.

Goose Lake Valley.—The abandoned Goose Lake valley leaves the Maquoketa River valley at its sharp bend northwest of Preston, in Jackson county, Iowa (Fig. 1.) It extends south across eastern Clinton county and joins the Wapsipinicon River valley six or seven miles above its mouth. At the divide near Goose lake (Pl. I), the floor of the channel has an elevation of about 670 feet, about 100 feet above the Mississippi. The surface material of Goose Lake valley passes downward into fine sand which is 60 to 100 feet thick on the divide south of Goose lake. Farther north in Secs. 17, 8 and 5 of Deep Creek township, Clinton county, several wells go 110 to 120 feet in sand and fine gravel. In the south part of the channel south of Elvira wells 70 to 80 feet deep do not reach rock. The surface of the bed-rock at this place is therefore more than fifty feet below the level of the Wapsipinicon river, four or five miles to the south, and more than twenty feet below the level of the Mississippi at the mouth of the Wapsipinicon. The material is usually largely quicksand, but in two cases, thick deposits of clay were passed through beneath 20 to 30 feet of quicksand.

THE PRE-GLACIAL COURSE OF THE MISSISSIPPI. . .

The deep well at Sabula located on the flood-plain (altitude 590 feet) reaches rock at a depth of 165 feet or at 425 feet above sea-level (Fig. 21). The town well at Fulton located near the level of the river reaches rock at an elevation of about 400 feet, and rock has been reached at elevations of less than 500 feet, at a number of places in the Mississippi valley between this region and St. Paul. Passing into the Narrows

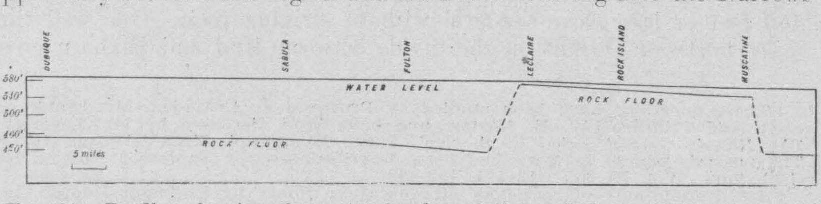


FIG. 21. Profiles showing the water level, and the rock-floor of the Mississippi valley across this region.

the river flows on a rock bed which has an elevation of 550 feet (Fig. 21) at Leclaire, 530 feet at Rock Island and 506 feet at Muscatine. Below Muscatine, the Mississippi valley again has an alluvial filling of 100 to 150 feet, and the elevation of the rock-floor is less than 400 feet at several places where deep borings have been made. At St. Louis the rock-floor is but 284 feet above sea-level, and buried by more than 100 feet of alluvial deposits.

From the elevations of the rock-floor and from the width of the valley at various points, it is evident that the stream which excavated the Mississippi valley above Albany and Clinton did not follow the present course of the Mississippi through the rock-bound, rock-floored valley from Leclaire to Muscatine. It must have escaped by some valley whose elevation was not more than that of the rock-floor above Clinton. It is clear therefore that changes of drainage, on a large scale, have taken place in this region, and that the present rivers do not in all cases follow the courses of those which preceded them.

The principal factor, if not the only one, which disturbed the drainage of this region was the ice of the glacial period.

The course of the Mississippi above the Narrows is the same as the pre-glacial course of the river which drained this region. But below Princeton and Cordova, the present course of the river is not its pre-glacial course. Below Albany, there are two possible courses, so far as now known for the pre-glacial Mississippi. It may have departed from its present course (1) to the west, flowing up the valley of the present Wapsipinicon, or (2) to the southeast, flowing through the Meredosia valley. But small portions of these two possible courses fall within the area covered by this bulletin, and a detailed discussion of the questions involved will not be attempted.[1]

From the discussions of Messrs. Leverett, Udden and Norton, it may be stated that the suggested course of the pre-glacial Mississippi in Iowa leads up the Wapsipinicon about twenty miles to the mouth of Mud creek (Fig. 22), thence southwest in a direction roughly parallel to Mud creek to Durant, thence on into Muscatine county, probably joining the Mississippi just below Muscatine.[2] In the portion of the Wapsipinicon valley through which the deepest part of the old course probably lay, wells go down only 35 to 40 feet in sand and gravel, and therefore do not tell us whether or not there is a former channel here corresponding in depth with the pre-glacial course of the Mississippi above Albany. Running in a general parallel direction with the course of Mud creek, but sometimes two or three miles to the south or east of it, there is a pre-glacial valley in which many deep wells have gone down to 450 feet or less above sea-level without striking rock. One well three miles north of Durant on the divide between Mud and Elkhorn creeks

1 These questions have been studied by Professor J. A. Udden, Mr. Frank Leverett, and Professor W. H. Norton, and have been discussed by Mr. Leverett in *The Illinois Glacial Lobe*, U. S. Geol. Surv., Monograph XXXVIII, pp. 463-467. The possible course in Iowa has been described also by Professor Norton, Iowa Geol. Surv., Vol. IX, pp. 413-415, 492-493.

2 See contour may of rock-floor of Muscatine county by Professor Udden. Iowa Geol. Surv., Vol. IX, Pl. VII, p. 322.

does not reach rock at 400 feet above sea-level. This channel has been called by Professor Norton the Cleona channel,[1] from a township in western Scott county.

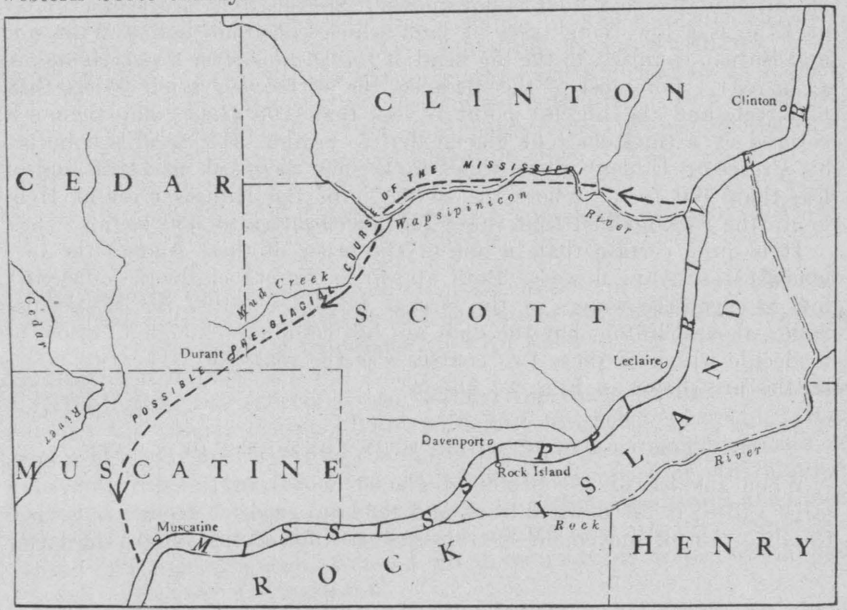


FIG. 22. Sketch map of a part of eastern Iowa showing a possible pre-glacial course of the Mississippi river.

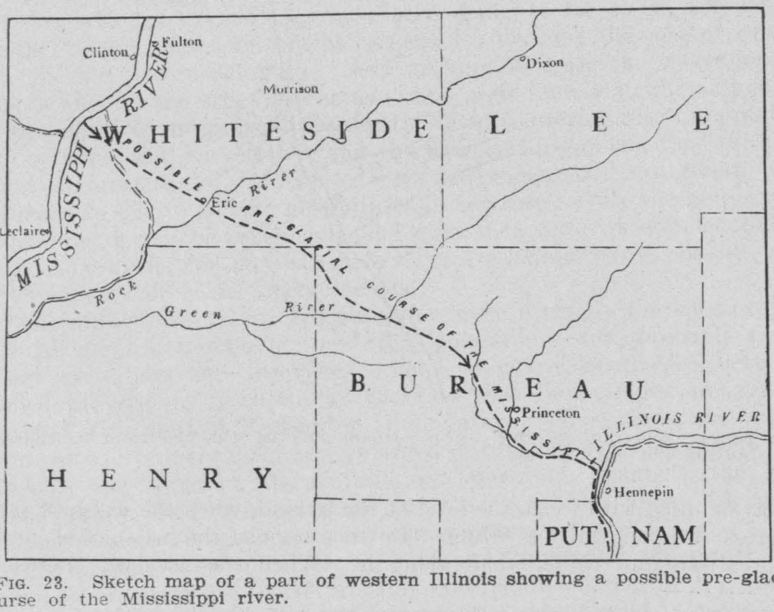


FIG. 23. Sketch map of a part of western Illinois showing a possible pre-glacial course of the Mississippi river.

1 Norton. Iowa Geol. Surv., Vol. IX, p. 493.

The portion of the Illinois course which lies within the area under discussion leads down the Meredosia to Rock river in the vicinity of Erie. No deep wells occur along this portion of this valley, and the elevation of the rock-floor is not known. Southeast from the Rock river at Erie, is a low lying tract of land which continues across Whiteside and Bureau counties, to the big bend of the Illinois river above Hennepin (Fig. 23). For most of the distance, the surface elevation is less than 650 feet, and the highest point is less than 700 feet. The region is covered by a thick body of glacial drift. Several well records collected by Professor Udden[1] along this course show bed-rock at elevations of less than 400 feet. Where the course joins the Illinois river at Hennepin the rock-floor of that valley has an elevation of 350 feet.

It is quite certain that in one or the other of these courses the preglacial Mississippi flowed. Both appear to have rock-floors sufficiently low to carry the waters of the stream which excavated the Mississippi valley above Clinton, but the data are not complete enough to allow us to decide which of these two courses was the real one. The two possibilities are shown in Figs. 22 and 23.

THE EFFECT OF AN ICE-SHEET UPON THE COURSE OF A RIVER.

When the ice of a continental glacier moves in the direction of a large valley, it fits down into it, and tends to erode it deeper, but when the direction of movement is transverse to that of the valley, the latter

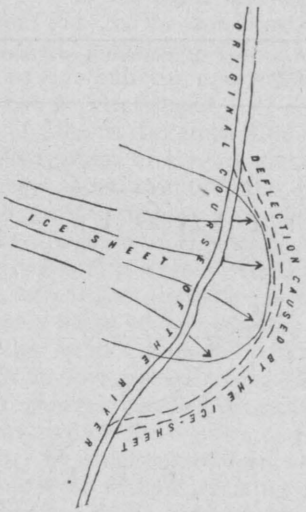


FIG. 24. Diagram showing how a stream may be deflected from its course by the advance of an ice-sheet.

may be filled with ice to the level of the upland, when the ice-sheet moves across it upon the ice filling. In this region, the ice moved toward the Mississippi rather than along it. When the ice-sheet encroached

1 From unpublished notes of Professor Udden loaned to the writer.

upon the valley from the west, the tendency was to deflect the drainage to the east around the margin of the ice. Being thus deflected from its regular course for a greater or less distance, it was compelled to find or make a new channel (Fig. 24). When the ice-sheet withdrew from the site of the old valley the stream might have returned to its former course, if the old valley had not been filled with drift. But if the old valley was largely filled, or if the new channel was cut deep, the stream might continue to follow the new course.

THE SUCCESSION OF POSSIBLE DRAINAGE CHANGES OF THE GLACIAL PERIOD.

If we knew the pre-glacial course of the Mississippi, it would be less difficult to outline the drainage changes caused by glaciation. As it is, the subject will have to be considered with the two possibilities already indicated in mind.

This region was especially well located for the diverting of streams during the glacial period. Three different ice-sheets advancing from the northwest, and two from the northeast, had their margins within or near this region, and the flood waters of a large part of still another ice-sheet flowed through the region by way of the Mississippi and Rock rivers. Lying just to the south of the unglaciated area, the region received throughout glacial times a great quantity of water which had flowed across the driftless area.

The succesion of the ice-sheets which entered this region and their extent has been given already (pp. 34-44). Some of the valleys which are now without streams may have been made, so far as we now know, at the time of any one of the several ice epochs; the age of others may be fixed more definitely. Any attempt to trace the succession of events and fix the order of changes can result merely in the statement of probabilities and possibilities, for the factors entering into the problem are so many and so variable, and the data so incomplete, that the possible combinations of drainage changes are numerous. No attempt will be made to discuss all the possibilities in the case. Only the more probable changes will be considered, and even then, positive statements can seldom be made, for in most cases there are a number of possible, and often equally probable interpretations.

The unoccupied valleys of the region were probably the sites of preglacial streams, though in some cases the valleys were probably small. That the valleys were in existence much as now when the ice-sheets invaded the region, is shown by the fact that their slopes are usually covered with drift of Kansan or Illinoian age. Once made, the valleys were probably re-occupied and enlarged during later glacial epochs, and possibly the Narrows, the Cattail and Meredosia channels, the Rock River valley, etc., were drainage courses more than once with intervening stages when they were without streams.

The first ice-sheet of which we have any knowledge, the pre-Kansan came in from the west. It probably covered the region of the Cleona channel (Fig. 22), and in that case it probably diverted to the eastward the stream which occupied that valley. If the pre-glacial Mississippi flowed through the Cleona channel (the Iowa course, Fig. 22) this ice-sheet, by filling and blocking the valley, may have diverted the master stream to the course which passes down the Meredosia, and continues southeast to the Illinois river at Hennepin (the Illinois course, Fig. 23).

If the pre-Kansan ice-sheet did not close the Cleona channel, the Kansan ice-sheet advancing from the west certainly did (Fig. 13). The ice then advanced eastward to the present channel of the Mississippi and beyond, doubtless pushing the river before it. When the Kansan ice-sheet melted away, the river may, so far as now known, have followed (1) the Illinois course, (2) the Meredosia-Rock river course, or (3) flowed through the Narrows as now.

With the advance of the Illinoian ice-sheet from the east, the Illinois course was doubtless closed (Fig. 15), and if the Mississippi river had flowed that way, it was forced to find a more westerly course. Possibly at this stage the Mississippi flowed for a time by way of the Meredosia valley to Rock river, and then down the valley of that stream (Meredosia-Rock river course), or it may have taken its present course through the Narrows at this time. Either of these courses could have been followed only temporarily, for the advancing ice probably forced the drainage farther westward.

At this maximum extension, the Illinois ice-sheet reached the Mississippi valley a few miles below Savanna, and the valley was probably closed to some point north of the mouth of Elk river. The ponded waters, extending up the Maquoketa and a tributary of this stream from the south, broke over a divide near Goose lake, and escaped south to the Wapsipinicon. This was probably the origin of the Goose Lake channel. But the lower course of the Wapsipinicon valley was blocked by the ice of the Illinoian epoch (Fig. 15), and the waters coming down the Goose Lake channel escaped westward up the Wapsipinicon to the mouth of Mud creek. Mud creek is a small stream, but it meanders over a broad flat which is often more than a mile in width. At the head of Mud creek, near the southeast corner of Scott county, the flat continues across the divide as a distant channel at an elevation of about 725 feet. Southwestward from the divide, the channel is followed by Elkhorn creek to the Cedar river at Moscow. Continuing southward in eastern Iowa, this course has been traced by Leverett[1] across several drainage basins until it joins the Mississippi in Lee county. Throughout its entire length it marks approximately the maximum extension of the Illinois ice-sheet, and is probably the course followed by the Mississippi when this ice-sheet was largest.

It is not probable that either the Goose lake or the Mud creek course was followed long after the Illinois ice-sheet withdrew; and yet the bottom of Goose Lake channel at the divide near Goose lake and to the north, is 70 to 100 feet below the rock outcrops exposed along its sides. If this was the only time that the Goose Lake channel was occupied

1 Leverett. U. S. Geol. Surv., Monograph XXXVIII, pp. 89-97.

by the main river, it must have been cut out and then silted up with the thick deposit of sand which it carries. Possibly the Illinoian ice-sheet occupied the Mississippi valley above Clinton for a time even before the lower end of the Wapsipinicon valley was closed, and if so, the full volume of the Mississippi may have flowed this way for a longer time, and cut out the deep valley in the rock. Later when the Illinoian ice-sheet pushed up the Wapsipicon valley, the level of discharge at the south end of the Goose Lake channel was raised, and the valley was silted up. The Goose Lake channel is lower than the Mud Creek channel, and the latter was probably abandoned first.

With the withdrawal of the Illinois ice-sheet, the Mississippi may have returned to the Illinois course, or it may, so far as now known, have followed the Meredosia-Rock River course, or its present channel through the Narrows.

Later came the ice of the Iowan epoch. The ice-sheet advancing from the northwest may have temporarily dammed the Mississippi river at Albany, and caused the waters to flow by the Cattail channel, or the ice may have pushed across the upper end of the Narrows and diverted the Mississippi down the Meredosia valley. The Iowan ice-sheet from the northeast probably closed the Illinois course, and furnished another opportunity for the opening of the present Rock River valley, or the shifting of the stream to the present course through the Narrows.

Whatever the order of development of the valleys, we may safely assume that they were all in existence, and in much their present form, by the end of the Iowan glacial epoch. Following that epoch the Mississippi may have flowed by either the Illinois course, the Meredosia-Rock River course, or by the present course through the Narrows.

The valley filling of the Wisconsin epoch has been considered in another chapter (Chapter IV). It is sufficient here to recall that aggradation went on until the valley bottom was raised to the level of the second bottoms, that is, about 40 feet above the present river level. The alluvial plain stretched from bluff to bluff, and the numerous divisions of the river probably wound about on the plain in irregular courses. The Garden Plain, Coe, and Moline uplands, as well as the smaller areas at Fulton, Clinton and Albany stood as island-like elevations completely surrounded by the alluvial plain. By all the abandoned courses (p. 56) except the Goose Lake channel, water from the Mississippi passed at various times during the stage of maximum valley filling, in the Wisconsin epoch. The river probably shifted frequently from one to the other, or divided and occupied several channels at the same time. At this time the water of the Mississippi may have passed by way of the valley south from Clinton or by the Cattail channel, and again by way of the Narrows or the Meredosia-Rock River course. In the last case, it may have joined the Mississippi by way of Pleasant Valley, or by the present Rock River valley, south of the Moline upland.

The waters escaped from the Rock River valley south of Erie, and passed over to Green river, and possibly for a time continued southeast to the Illinois river. During the maximum advance of the early Wisconsin ice-sheet, this southeastward course was closed; and probably a large area of the lowland tract extending from Rock river to the Illinois river was flooded, and may have been drained westward by way of the Green River valley.

The filling of the valleys has been discussed as though it all took place during the Wisconsin epoch, but it is not meant to imply that this was necessarily the case. We do not know that the Mississippi valley was ever completely cleaned out after the earlier glacial advances, and some of the deeper deposits may be of an early glacial age. There were probably a number of periods of alternate filling and deepening of the valleys, with the advances and retreats of the several ice-sheets. Evidence of a period of erosion in the valley would be obscured or obliterated by the next period of deposition, and evidence of deposition by the next period of erosion. Satisfactory evidence has not even been obtained for the fixing of terrace levels of early Wisconsin age, as distinct from those of late Wisconsin age. The material exposed in the several sand pits previously described may be traced up the Rock and the Mississippi valleys to the Wisconsin drift farther north.

The absence of great bodies of ice-deposited drift in the bottom of the Mississippi valley, in contrast with its presence in the filled Cleona and Illinois channels, may be explained by the fact that the Mississippi valley above Clinton has continued to carry the river, and even though its bed may never have been cut down to its former level since the early glacial epochs, the scour and fill of later times may have reworked such drift deposits as were left in the channel, and the stream may have carried away the finer material. The Missouri river at Blair, near Omaha, scours to bed rock, at a depth of 40 feet, in times of flood,[1] and at Nebraska City the scour is believed to occasionally reach 70 to 90 feet.[2] Recent studies of the Mississippi river at St. Louis indicate a scour of considerable depth at that place, and probably this is a more important process in the valleys of great streams than has been commonly recognized. If the floods of the present are sufficient to effect this amount of scour, it seems probable that the glacial floods may have scoured to the rock bed in times of flood even where the valley filling is the greatest. A number of well records in the Cleona and Illinois courses show considerable unstratified glacial drift, indicating that these valleys were never completely cleaned out after they were filled, nor was the material worked over as by scour and fill.

SUMMARY OF DRAINAGE CHANGES AND APPLICATION TO CERTAIN VALLEYS,

The Narrows.—The present valley of the Mississippi below Princeton and Cordova is narrow, but the slopes are gentle, and largely covered with drift (Pl. 16 A). In some places the slopes are so gentle that they are cultivated down nearly to the river.

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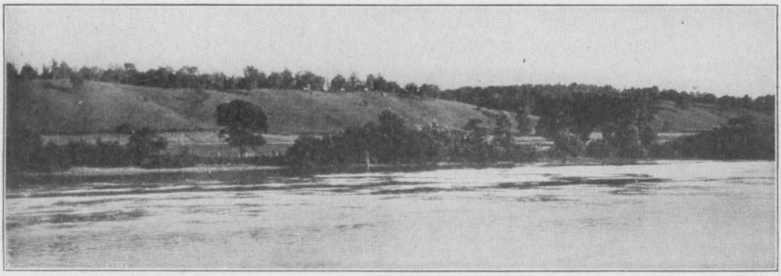
1 Gerber. Cited by Todd. Bull. 158, U. S. Geol. Surv., pp. 150-151.
2 Cooley. Rept. of U. S. Engineers for 1879-80, Pt. II, pp. 1066 and 1071.



A. Illinois bluff north of Hampton, showing the gentle drift covered slopes of the Narrows.

B. Road cut in loess, Sec. 24, Phenix township, Henry county, Illinois.

Just west of the Tile Works, south of Leclaire, a cut of the I. & I. Electric Ry. exposes a considerable thickness of gravelly Illinoian drift, at an elevation of about 50 feet above the river. The drift rests on a stratum of well cemented, horizontally bedded gravel (Pl. 10, A), which is probably of Yarmouth (Buchanan) age (p. 37). These materials show no indication of having been disturbed since they were deposited, and are apparently in place.

Illinoian drift was seen in a number of other exposures, well down in the valley along the bluff from the Tile Works to MacArthurs. In some places the drift appears to have a thickness of 15 feet or more, but slumping is constantly going on, and obscuring the vertical exposures. The gullies cutting back into the bluff between Princeton and Leclaire show many exposures of Illinoian drift, and this is true throughout the entire course of the Narrows.

The great quantity of drift found on the slopes and down in the valley, and its apparently undisturbed condition, indicate that a valley existed where the Mississippi now flows through the Narrows at the time of the Illinoian glacial epoch, and that the bluffs had already been weathered back to quite gentle slopes. This interpretation would place the origin of the channel through the Narrows, either in the pre-Kansan or Kansan glacial epoch, and it would seem necessary that the drainage followed this course for at least an interglacial epoch to account for the size of the channel.

It also appears that the valley was open during the Wisconsin glacial epoch, for river deposits of this epoch occur in the valley. To this epoch are referred the red clays exposed north of the stone quarry north of Leclaire, and the cross bedded sands of the terrace just east of Pleasant Valley, at the end of the spur of upland extending southwest past MacArthurs. This terrace is about 40 feet above the river, and corresponds in elevation and material with the terraces of Wisconsin age.

Rock River Valley and Pleasant Valley.—It is difficult to determine when that part of the Rock River valley within this region, and Pleasant valley, originated. As already stated, they may have originated during the Illinoian epoch of glaciation, or at the time of the advance of the Iowan ice-sheet from the east. It is also possible that one of the western ice-sheets may have produced conditions that caused their opening, although this is less probable. If the ice of the Iowan epoch which advanced from the east, lay across the Illinois course at the same time that the ice from the west reached its greatest extension, and closed the upper end of the Narrows, the ponded waters may have escaped by way of th Rock River course, and opened this channel.

It may be significant to notice, as pointed out first by Udden, that Pleasant valley is in line with a continuation of Duck Creek valley on the Iowa side, which for more than ten miles is parallel with the course of the Mississippi though the water flows in the opposite direction. Duck Creek valley continued up Pleasant valley, may mark the course of some pre-glacial stream which flowed eastward up the present Rock river course, or passed south through the gap now occupied by Rock river, and then eastward up the Green River valley.

The pre-glacial Rock river apparently did not cross this region, but passed south from its present course at Rockford through eastern Ogle, Lee and Bureau counties to the Illinois river.[1] It was diverted to the westward by one of the ice-sheets which advanced across Illinois from the east, most probably the Iowan with the northern margin of which its course corresponds, approximately, for much of its diverted part. Across the southern part of this region the valley of Rock river is wide for the stream which now follows it, and the bluffs usually show evidence of recent cutting. The Mississippi apparently followed this course for a considerable period of time, probably from the Iowan epoch to the Wisconsin epoch and even since the latter, a part of the Mississippi flowed this way, apparently until a very recent time.

As the Rock River valley has been compared with other valleys of the area, a factor which has certainly aided in its development should be noted. The valley in its lower course is cut in Coal Measures shales down to the contact of Devonian limestone below. The valley floor is commonly underlain by the limestone, and the stream has shifted back and forth over this floor, and undercut the softer fomation in the bluff. The contact of the limestone and shales also appears to dip to the south, and the stream has apparently shifted down this slope undercutting the south bluff. These factors of material and structure have probably been important in developing the broad valley.

The Cattail Valley.—The Cattail channel was most probably caused by the closing of the Mississippi valley between Clinton and the Meredosia valley. This closing may have been effected by the pre-Kansan ice-sheet, and was certainly accomplished by the Kansan and the Iowan. It seems necessary to assign the cutting of the Cattail valley to the time of one of the earlier ice-sheets, for its slopes are covered with drift of Illinoian age. The valley was probably re-occupied by the river during the Iowan epoch, and was certainly followed by the drainage of the Wisconsin epoch, for it is lower than the second bottoms.

One of the ice-sheets from the west probably caused the diversion which made the Albany channel, and again it seems more probable that it was one of the earlier advances, because of the presence of bowlders which appear to be of Iowan age in the channel. The narrow channel between Fulton and Lyons, and the one passing through the west part of Clinton may have been caused by the water breaking over low spurs of the west bluff, as the Illinois ice filled the valley.

POSSIBLE DRAINAGE CHANGES OF ELK RIVER.

Another probable drainage change which may properly be mentioned at this place, is that of Elk river in the northeast corner of Clinton county, Iowa. The area is shown in Fig. 25. The west branch of Elk river flows eastward through Secs. 11 and 12 of Elk River township through a very rugged country, in a narrow steep-sided valley,

[1] Leverett. U. S. Geol. Surv., Monograph XXXVIII, p. 484.

125 to 150 feet deep. In the west part of Sec. 7, T. 83 N., R. 7 E. (Elk River township), it joins the north branch, and Elk river then flows south through Sec. 18, turns sharply to the east, and cuts through the Mississippi bluff by a very narrow valley just north of Elk River Junction. To the northwest of Elk River Junction, a re-entrant occurs in the Mississippi bluff, and a broad low valley leads off to the northwest through Secs. 24, 14, 15, 10 and 3. It is followed by the branch of the C., M. & St. P. Ry., running northwest from Elk River Junction. In the N. E. quarter of Sec. 15, Elk creek enters this valley from the west, and flows north in it nearly to the north line of Sec. 10, where it joins the west branch of Elk river coming down the valley from the northwest, and the stream then flows eastward through the narrow channel of Secs. 11 and 12 just described. The divide between Elk creek flowing to the north, and the drainage to the southeast is near the west line of Sec. 14, and is only 20 to 30 feet above the level of Elk river where it leaves the valley in the north part of Sec. 10.

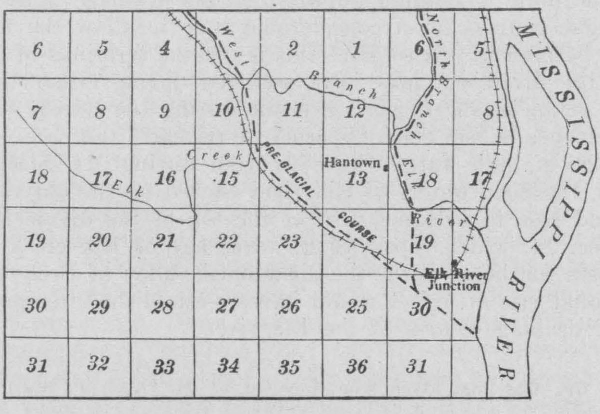


FIG. 25. Map of Elk River township, Clinton county, Iowa, showing a possible pre-glacial drainage and its relation to the present drainage. The pre-glacial courses suggested are indicated by the broken lines.

The re-entrant of the Mississippi bluff southeast of Elk River Junction also connects northward over a low divide in the west part of Sec. 19 with the southward flowing part of Elk river, at its sharp bend to the eastward near the south line of Sec. 18. The divide between Elk river and the re-entrant of the Mississippi bluff to the south is about fifty feet above Elk river, or about 650 feet above sea-level. A well near the crest of the divide in the N. 1/2, S. W. 1/4 of Sec. 19 was reported to have gone 163 feet in clay and sandy material, or down to an elevation of about 500 feet. Several wells located in Secs. 14 and 24 in the valley followed by the C., M. & St. P. Ry. northwest of Elk River Junction go 20 to 30 feet in sand, and a well in the north part of Sec. 10, just south of where Elk creek joins Elk river, goes 118 feet to bed-rock. Wells at Huntown reach a depth of 200 feet without striking rock,[1] from the topography and the well records just given, the following explanation is offered:

In pre-glacial times the stream flowing southeast across Sec. 3, continued in that direction across Sec. 10 in the valley now followed in the opposite direction by Elk creek. It was joined in the N. E. 1/4 of Sec. 15 by Elk creek, and the stream continued southeast to the reentrant of the Mississippi bluff southwest of Elk River Junction. The north branch of Elk river came in as at present along the west line of Sec. 18, but continued south across Sec. 19 along the course marked by the well record previously given.

With the advance of the Kansan ice-sheet from the west, the southeast course may have been closed, and the west branch turned across Secs. 11 and 12 to join the north branch. But as their common mouth was closed, the ponded waters passed up a small valley heading to the eastward in Sec. 18, and broke over a low divide along the present course through the bluff. It would appear that the drainage must have been held in these courses for a considerable time to allow the new valleys to become permanent. Also since this is not the terminus of any known ice-sheet, the diversions may have occurred during either the advance or retreat of an ice-sheet, most probable during the retreat or during a slight readvance in the general period of retreat.

At a time of high water which occurred during Mr. Starr's visit to the region, the flood waters of Elk river backed up the old valley across Sec. 10 and rose to within 6 feet of the top of the divide in the west part of Sec. 14, which separates the drainage of Elk creek from that which passes southeast down the abandoned valley of Secs. 14 and 24. An additional rise of 6 feet would have re-established, temporarily, the pre-glacial drainage course of the Elk river.

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1 Part of the data just given was collected by Mr. Leon P. Starr during the summer of 1907.

CHAPTER VI.

EOLIAN SAND AND LOESS.

The Loess.

GENERAL CHARACTERISTICS.

The loess is a yellow loam, grading from clayey on the one hand to sandy on the other, which forms a coating over most of the upland region. In its most typical phase the loess is fine grained. When dry it forms a powder, smooth to the feel, and without grit of any sort. But the loess of this region in many places takes on sandy phases, and the sandy loess passes into fine sand, both vertically and horizontally, by the most gradual transitions. In some places, fine grained loess may overlie, underlie, or be interbedded with sand which has been shifted by the wind (*eolian sand*). The best examples of association of loess and sand are found on the border of the upland south of the Wapsipinicon river, in northern Scott county, Iowa, and are treated more fully under "Bluff Border Dune Areas" on page 76. In the other direction, the loess grades into a clay which is more sticky when wet, and does not pulverize so readily when dry. This phase often has a silty, banded appearance. Though the materials classed as loess are quite variable, they are so closely associated, and grade into each other so commonly, that it is impossible to separate them.

The thickness of the loess varies from a thin veneer of a foot or less, to a thickness of 15 or 20 feet, or rarely 25 to 30 feet. Its average thickness is probably about 10 feet. It is thickest on the edge of the uplands overlooking the great valleys, and thins back from the bluffs. With respect to the small valleys, it is usually thickest on the divides where erosion has been least effective, and thinner on the slopes. In the driftless area, and the area of Kansan drift, it has in many places been removed from the steep slopes, while on the divides it may have a thickness of 15 or 20 feet.

In many exposures the loess appears almost structureless, but where it passes into sandy loess, or into the clayey silty phase, structure is more prominent. Where it becomes sandy, cross-bedding like that of dune sand appears, and where it becomes silty, layers appear, which because of their varying porosites, are distinct on the face of the exposure. In most cases the bedding conforms to the slope of the surface, but some exposures show horizontal bedding at least in their lower parts.

A prominent characteristic of the loess in most regions is its ability to stand in steep cliffs. Steep faces of it may be found in this area where it has its normal texture, but over part of the region the loess is so sandy that it slumps readily. Steep loess banks 10 to 20 feet high may be seen in pits and road cuts throughout the area (Pl. 16, B). A good loess exposure may be seen in a "clay pit" near the south line of Sec. 1, Clinton township, just north of the road leading west up the bluff from the north part of Clinton. Good exposures are also found along the bluff front in Davenport, Rock Island, and Moline, and in a number of road cuts through the bluff in Moline, and east along the bluff to East Moline.

In general the loess has little effect upon the topography, for it is essentially a thin veneer over the surface. Locally the more sandy phases of the loess, in association with dune sand, are of more importance topographically. The topographic effect of the sand and loess is identical with that of dune sand (p. 75).

DISTRIBUTION.

The loess occurs throughout the region from the highest divides down to, but not in the river flats. It forms a coating over the driftless area, over all the drift-sheets of the region, in some places over sand and gravel terrace deposits, and even over some of the dunes. Its distribution is independent of the underlying material, and of the altitude of the surface on which it rests. On the edge of the uplands south and east of the large valleys, there are usually belts 1 to 2 miles wide in which dune topography predominates, and where the material is dune sand or sandy loess. Back from the edges of the upland, the sand becomes finer and grades into sandy loess, and then to loess. In general, the loess of the east side of the Mississippi is coarser and more sandy than of the west side. The clayey phase of loess is rarely present on the Illinois side within the region studied. West and north of the great valleys, the belts of sand or sandy loess on the edges of the uplands are not so prominent, or do not appear. The loess on the Iowa side is as a rule a fine grained clayey loam.

SUB-DIVISIONS OF THE LOESS.

Three zones may usually be recognized in the deeper loess cuts. (1) At the surface a weathered and leached zone of brownish clayey earth mixed with more or less humus. This surface part is sticky when wet, and on drying breaks up into roughly cubical blocks. This zone is usually two to three feet thick, though rarely as much as eight feet, and grades down into (2) normal loess, which consists of a yellowish pebbleless loam. At the base, a zone (3) of light bluish or ash-colored loess is often found. The middle division forms the bulk of the deposit, and to it the characteristics already noted belong.

The blue loess may be seen at various places throughout the region where cuts show the full section of the loess. Where the loess as a whole is thin, the basal member does not usually occur; but where the loess is 10 to 15 feet thick, the bluish or grayish phase is likely to be present. It is often more silty than the yellow loess above, and even where it is absent most of the loess becomes more silty toward the base. The blue loess is usually seen in fresh exposures only. The contact between the blue and yellow phases is locally sharp, while in other places the transition is gradual, and stringers of the yellow extend down into the blue. In exposures which are not fresh, the face of the bluish part often has a yellow coating. Exposure for a few months may suffice to change the bluish color yellowish. Professor Udden says that he has seen the change from blue to yellow and from yellow to blue alternate with the seasons, as follows: In a deep road cut at Rock Island the loess of the road bed works up into a yellow dust several inches deep during the summer months. In the winter, snow covers the ground, moisture is present, and by spring the material of the road-bed is a blue mud, only to change again to yellow loess during the following summer. From these facts it appears that the color is determined by some change which takes place with exposure to the sun and agents of weathering. The blue loess was found only where moisture was abundant, and moisture was probably important in changing the yellow loess to blue in the instance cited. The change from blue to yellow is probably due to oxidation, and the reverse to deoxidation.

Since change may take place, several questions may be raised concerning the original condition of the loess. Was it all yellow when deposited and has the lower part since changed to blue? Or was it all originally blue, and has the upper part changed to yellow by oxidation? Or was it blue at the base and yellow above, as at present, from the beginning? Since moisture seems necessary for the existence of the bluish phase, would it not all be blue if deposited in water, or if it lay below the level of ground water?

CONCRETIONS.

The loess usually contains considerable limey material as may be shown by the test with hydrochloric acid (p.). Nodular concretions (*loess-kindchen*—children of the loess) of lime carbonate are often abundant. These loess-kindchen may be roughly spherical nodules of concentric structure, or irregular in form. They vary from nearly pure calcium carbonate, to masses of loess cemented by lime carbonate. Those of pure calcium carbonate have a grayish color, and look somewhat like limestone pebbles. They usually have diameters of less than an inch, but larger ones may be found locally.

In the blue phase of the loess, there are in places tubular concretions of iron oxide, with concentric structure around a central opening. They have a reddish or yellowish color, and are usually less than a half inch in diameter. They occur in an upright position, and on the eroded surface in the gullies they stand up like small twigs of wood. Washed out from the loess, they soon harden and sometimes strew the surface like pebbles. A number of these concretions were found with a small thread-like root through the central opening, and this gives a clue to their origin. Water passing down along the root deposited iron oxide around it, and later in concentric layers around the enlarging case. In places the iron oxide is not deposited in sufficient quantity to form a solid tube, but it may stain the loess in concentric layers. These stained portions have a vertical position and locally attain a diameter of 3 to 4 inches.

FOSSIL SHELLS.

Shells of small snails may often be found in the more compact phases of the loess, but seldom in the sandy phases. Fine grained loess containing many fossils, may pass into sandy loess, when it at once loses its fossils. Fossils are rare on the Illinois side of the river where the loess is sandy, but are more common on the Iowa side. Collections of loess fossils were made from several localities, and all are common types of land snails. Forms similar to many of them are now living on the surface in the same region.

RELATION OF THE LOESS TO THE VARIOUS DRIFT-SHEETS.

The loess overlies the Kansan and the Illinoian drift-sheets. It is present over most of the Iowan drift within this region, but this is because of the narrowness of the belt of Iowan drift. Where the Iowan drift is more extensive, the part back from the borders, is largely free from loess. Both the Kansan drift and the Illinoian drift beneath the loess are leached and weathered to a depth of several feet, and they are locally separated from the loess above by soil horizons and interglacial deposits. On the other hand, the Iowan drift is fresh up to the base of the loess, and the two often appear to grade into each other. It seems, therefore, that the main body of the loess is closely associated with the Iowan drift, and that it was formed, or at least its deposition was begun, during the maximum extension of this ice-sheet, or soon after its retreat, before weathering had produced much change in the Iowan drift.

AN OLDER BROWN LOESS.

At several places along the road leading north from Argo, Clinton county, Iowa, toward the Wapsipinicon bottoms, what appears to be a brown loess may be seen in the road cuts. It is very ferruginous, with many tubular concretions and seams of cemented material which are locally so hard as to have a metallic ring when struck. In the more ferruginous parts the color is quite red. This deposit is overlain by yellow loess, which does not appear to be an alteration of the brown loess below. The deposit occurs in the region covered by the Illinoian ice-sheet, and although none of the exposures seen showed Illinoian drift below it, there is little doubt that it rests upon this drift. A similar old loess occurs in a number of the eastern counties of Iowa. It is described by Professor Calvin, from Winneshiek county[1] as resting on an eroded surface of Kansan drift, and was itself old, weather stained, and altered, before the deposition of the yellow Iowan loess. It is probably a weathered and altered loess of Illinoian age.

ORIGIN OF THE LOESS.

A detailed discussion of the origin of the loess will not be attempted.[2] We may, however, note the various hypotheses of its origin that have currency and see by which hypothesis the facts of this region are best explained.

The origin of the loess has long been in dispute. It was previously thought to be an aqueous (water-laid) deposit, made in lakes and swollen rivers during the melting of the ice-sheet. Others, recognizing the difficulties of the aqueous hypothesis, and noting the similarity of much of the loess to wind blown (eolian) dust, put forward the hypothesis that the loess is wind blown dust. Accoring to this hypothesis, the fine loess dust was picked up by the wind from the flood-plains of streams flowing away from the ice front, or from the surface of the freshly exposed drift as the ice retreated, and carried out over the adjoining country where it settled and formed the loess. Some students of the problem have combined the two hypotheses, believing that the loess is in part of aqueous and in part of eolian origin.

To the hypothesis of aqueous origin of the loess there are grave objections. We have seen that it is found on the highest points of the region, and in fact appears to have a fondness for high places, and this is true throughout its extent. It is hard to conceive of the submergence of the loess covered portions of the Mississippi basin to the extent demanded, without the submergence of the much larger area of surrounding land which is no higher, but which is without loess. Rivers, even when flooded, can hardly be considered capable of overtopping the highest parts of the country. There is no evidence of physical changes that might have produced a depression of the region or a damming of the Mississippi basin. Various explanations have been offered to explain its distribution by the aqueous hypothesis, but none of them appears to be adequate. Further, the fossil snail shells of the loess are the shells of species which live on the land, not in the water. The aqueous theory also fails to explain the thick deposits of more sandy material on the east and south bluffs.

The eolian hypothesis encounters some objections, for the basal part of the loess of some exposures shows evidence of having been deposited in water, and this grades upward without a break into the massive loess deposits.

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1 Calvin, Iowa Geol. Surv., Vol. XVI, p. 126.

2 The following references are given for the benefit of those particularly interested in the subject. Jour. of Geol., Vol. V, 1897, pp. 795-802 (Chamberlin); Bull. Geol. Soc. Am., Vol. IX, 1897, pp. 6-9 (Udden); Am. Jour. Sci., Vol. XVIII, pp. 106-112 (Hilgard). Additional references on the occurrence and the origin of the loess may be found in Chamberlin and Salisbury's Earth History, Vol. III, p. 411.

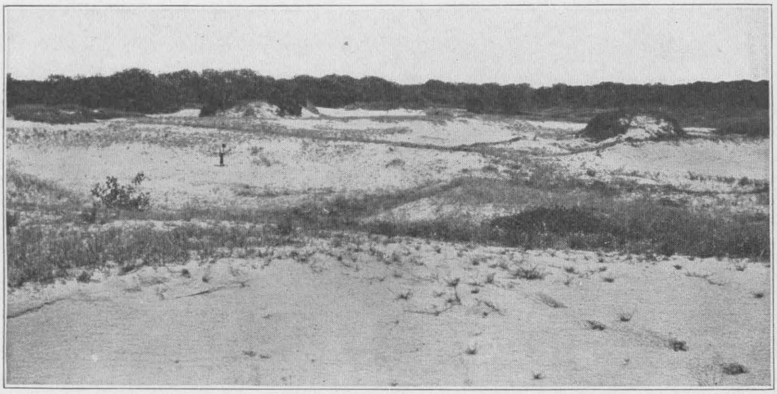
The best explanation of the loess seems to be made by a combination of the aqueous and eolian hypotheses somewhat as suggested by Professor T. C. Chamberlain.[1] The water flowing out from the melting ice carried great quantities of rock flour which were spread out over the flood-plains of the swollen streams. When the streams went down, and the flood-plains became dry, the wind picked up the fine silt and carried it out over the adjoining country where it was deposited. The material which settled directly from the atmosphere upon the land probably formed the typical structureless loess, that falling into pools, ponds, marshes, etc., or on areas temporarily flooded, took on a silty stratified appearance. Some of the material was washed down into the small valleys and deposited there. Depending on the degree to which it was mixed with the alluvium of the streams, deposits were formed ranging from positively identifiable water-laid clays and silts, through silty loess, to typical loess. In this, we have the explanation of the much commoner appearance of silty loess along valleys and on lowlands than on the uplands where typical loess or sandy loess is usually present.

On the other hand, as the winds which carried the loess became stronger, the material carried was coarser, and so there might occur in any locality all gradations from loess to sandy loess and fine sand. In periodic variations in the strength of the winds, we have the explanation of the interbedding of loess, sandy loess, and fine dune sand. By this combination, the aqueo-eolian hypothesis of the origin of the loess, the phenomena of this region are best explained and not only does it afford the best explanation, but all the conditions and processes postulated by the hypothesis are natural and to be expected at the close of an ice epoch. The larger part of the upland loess was probably deposited where it now lies by the wind.

The broad flats of the Mississippi and Wapsipinicon rivers within our region, covered by water during times of flood and exposed to the winds during the dry seasons, furnished a gathering ground from which the loess was taken up to be spread over the adjoining regions, thickest near the bluffs and decreasing gradually with distance from the great valleys. As our strongest and prevailing winds are from the west, more and coarser material was carried out over the east bluffs than in the opposite direction, and the more prominent bluff border areas of the east side of the Mississippi were formed. Large streams like the Mississippi, carrying the flood waters away from the glaciated region furnished gathering grounds for the winds far beyond the glaciated region, and so we find loess deposits bordering the Mississippi all the way to the Gulf of Mexico.

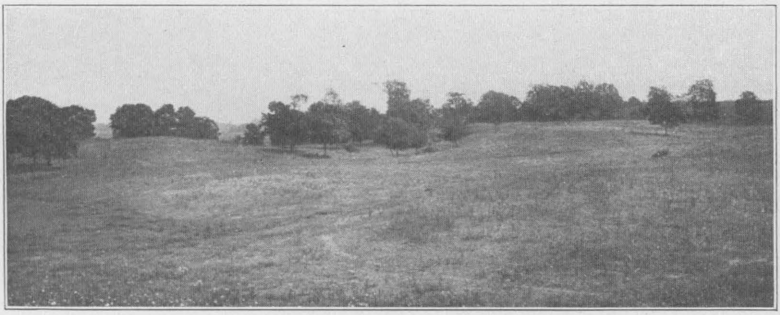
Most of the loess was probably deposited either while the ice was on, being carried out by streams flowing away from the ice margin, or just after the retreat began, before vegetation covered the surface. But the process continued long after the ice withdrew, and probably loess is yet being formed. As previously stated the main body of the loess appears to have originated during or soon after the Iowan glacial epoch; but loess was deposited at other times also.

[1] Loc. cit.



A. Sand dune areas on the Cordova flats, Rock Island county, Illinois.

B. Sand dune area in Sec. 3, Garden Plain township. The area on the valley flat passes gradually into the bluff border area in the background.



C. Fixed dunes south of Erie, Henry county.

DUNE AREAS AND THEIR DEVELOPMENT.

At various places within the region there are areas of dune sand practically free from vegetation, and when the surface is dry the sand is shifted by every strong wind. Associated with these treeless shifting dunes, and covering a much larger area, are dunes with occasional shrubs and trees, and a sparse covering of grasses (Pl. 17, A). These pass by successive gradations through areas with only an occasional patch of shifting sand (Pl. 17, B), to those in which the sand is completely fixed by vegetation, but in which the characteristic dune topography indicates the nature of the deposits below (Pls. 17 and 18, A). All gradations from shifting to fixed dunes occur in close association. All areas in which dune topography is distinct, whether the sand is shifting or fixed, have been mapped together (Pl. I). There are many small patches of dunes, some of them consisting of only a few small hills, both on the valley flats and the uplands, which because of their small extent, have not been represented on the map.

The topography of dune areas is very characteristic. It includes small hills or mounds, or sometimes ridges and enclosed depressions, all of which are more or less irregularly placed. The hills are formed by the piling up of the sand by the wind. The depressions result in some cases from the scooping out of the material of which the hills are made, and in others they are merely low places about which the dunes were built up. Some of the depressions have no outlets, and if the sand were not so porous, they would probably contain ponds and lakes. In fact, a few ponds do occur in the bluff border areas. Within the region all gradations may be found from characteristic dune topography, to a topography well controlled by stream erosion; for most of the dune areas with which we have to deal, have become more or less fixed and have been subjected to erosion for various lengths of time.

The dune areas of the region occur (1) on the valley flats, (2) along some of the margins of the upland forming the *bluff border areas,* and (3) in a few places on the upland back from the bluffs.

DUNE AREAS OF THE LOWLANDS.

The dune areas of the valley flats are usually 20 to 30 feet above the general elevation of the flats. They have a relief of 15 to 25 feet. These dunes are, for the larger part, shifting, and the vegetation upon them consists of isolated tufts of grasses and low shaggy bushes adapted to this environment. The more the vegetation, the less the shifting of the sand. The material is fine-to-medium grained sand, which has been drifted together from the sand deposited in the valley during the Wisconsin glacial epoch.

One of the best developed dune areas of the valley flats is in Sec. 34, and the east part of Sec. 33, Cordova township, 3 miles east of Cordova. In a large part of this area the vegetation is very sparse, and the surface shows only white sand (Pl. 17, A).

At the northwest corner of the Garden Plain upland there is a sand dune area partly on the valley flat, but continuing southeast by a gradual rise into the bluff border area. Vegetation is scant, and considerable areas of shifting sand occur (Pl. 17, B). In the northwest corner of Fulton township, Secs. 1 and 2, there is an area of about a square mile of characteristic topography with patches of shifting sand. Other dune areas of the lowlands occur in Secs, 29, 20, ad 21 of Newton township on the Meredosia bottoms south of the Garden Plain upland, in Secs. 30, 29, and 28 of Fenton township, 2 miles north of Erie, along the road leading west from Erie through Secs, 1 and 2, at several places on the Cordova flats, on the Wapsipinicon bottoms in the north part of Sec. 20 of Princeton township, and at several other places.

The tract of land intermediate between the lowland and upland, extending to the southeast from Rock river, south of Erie, and which has been described as a drainage course of glacial times, has a surface material of sandy loess and sand. Areas of characteristic dune topography (Pl. 17, C) appear on this plain, and the dunes rise 40 to 60 feet above the general level. Most of the dunes are fixed, but many small patches of shifting sand may be found.

BLUFF BORDER DUNE AREAS.

The bluff border dune areas include those areas along the margin of the uplands, in which the topography has been more or less determined by eolian deposits, and in which shifting dune sand may occur. As mapped, the areas include many patches in which the topography has been completely modified by erosion, but they have been included because of the origin of the sand. The boundaries of these areas are approximate.

The bluff border dune areas are usually higher than the upland immediately back of them, and viewed from that side appear as low ridges (Fig. 18). From the crest of the ridge one overlooks the valley on one side, and the upland on the other. The topography of the belt is in places quite rugged, and the relief considerably greater than that of the dune areas of the valley flats. Furthermore, the relief is often increased by erosion.

The surface of these bluff areas may consist of sand, sandy loess, or loess, or any mixture of these materials. The surface material is usually loess or sandy loess, which grades into coarser deposits below. The material, however, differs with the location, as will be noted later. Much of the surface carries a thin soil horizon of sandy or clayey material and is fixed by a covering of vegetation. When the soil or loess covering is removed, the sand may begin to shift. Areas of shifting sand, though occuring at various places, are not prominent features of the bluff border area.

From Rush Creek to Savanna, the bluffs bordering the river are covered with a thick coating of loess which in places is sandy. Southeast of Savanna, sand becomes more abundant and where the C., B. & Q.

A. Dunes consisting largely of loess, Scott county, Iowa. (Calvin.)

B. A small lake occupying a depression in the loess dunes, Scott county, Iowa. (Calvin.)

Ry. cuts the bluff in Sec. 19, Mt. Carroll township, a high bank of sand is exposed, and the bluff is capped by sand hills. Continuing south, to the upper end of the Cattail slough the bluff border dune area is a half mile to a mile wide. Here it becomes less prominent, and merges into a sandy tract which lies east of the Cattail channel, and continues eastward toward Morrison. North of Otter Creek, the dunes are largely fixed, small banks only showing sand that may be shifted. In Sec. 21, of York township, south of Johnson creek, a small patch of shifting sand occurs. South of Otter creek, hills of shifting sand are more common and in Secs. 19, 30, and 31 of Ustick township, they are numerous.

Along the north and northwest border of the Garden Plain upland, the bluff border dune area is prominent, and stands considerably higher than the upland to the southeast. It continues south along the west bluff of the upland, but east of the Albany channel it contains little sand. At the southwest corner of this upland, south of Albany, sand becomes more abundant, and the dune topography continues east along the bluff almost to Rock creek.

The northern portion of the Fulton upland, where the material is sandy loess and sand, shows dune topography which is very irregular and hummocky. The Clinton upland has dune topography, where the material is fine sand. The southwest part of the Albany upland south of the town shows pronounced dunes. They are fixed and the material is fine sand or sandy loess. The hill of rock in the village of Cordova carries a fine sand deposit, and an area of dune topography.

South of the Wapsipinicon river there is a bluff border area of fixed dunes (Pl. 18) consisting of loess, sandy loess, and sand. These materials occur in very intimate association both horizontally and vertically. In some places the dunes appear to consist entirely of loess, and road cuts expose a considerable thickness of it, while in other places close at hand, the dunes are of sand. In Sec. 28, Princeton township, a considerable deposit of coarse dune sand was found overlying loess, while farther west in the same section the sand hills are overlain by 2 to 6 feet of loess. When this is removed, the sand may be shifted about. Dune topography is well developed in Secs. 29, 28, 33, and 34 of Princeton township. Where the north-south road crosses Sec. 29 (Pl. 18, A) the material is loess, at least for 3 to 5 feet down, and a road cut just south of the crest of the ridge shows 15 feet of loess with the usual loess fossils. The topography is that of dunes whether the material is dune sand, dune sand coated with loess, or even typical loess down to a depth of 15 to 20 feet. The region shows that it is possible for dune topography to be developed in loess.

The north border of the Coe upland from Cordova eastward to the point of the upland west of Erie, has a bluff border dune area half a mile to a mile in width. The area has been greatly modified by erosion, but some of it still shows the topography characteristic of wind deposits. The material is fine sand passing into sandy loess.

South of the north margin of the Coe upland, bluff border areas of sand are found only in the most favorably located places. Thick deposits of loess occur on the margins of the uplands, but the topography has not usually been sufficiently affected by the eolian deposits to warrant mapping them in the bluff border dune areas. The west end of the upland between Rock and Green rivers has a dune topography, west of the middle of Sec. 31, Hanna township. Farther east the upland is coated with loess, even up to the edge of the bluff, until the low sandy plain which begins in eastern Phenix township is reached. In the valley of Rock river south of Moline, just beyond the Moline bridge there is a long, island-like, elevation on the valley floor. The west end of the island has dune topography and in some places the sand is now shifting. Along its lower slopes, the sands and gravels of the Wisconsin terrace (p. 48) are exposed.

The border of the Iowa bluff of the Mississippi is free from dunes, but is covered with typical upland loess. On the north bluff of the Wapsipinicon just east of its junction with the Goose Lake channel, there is a small area of dunes. The sand was blown up from the sandy flat to the west at the mouth of Brophy creek.

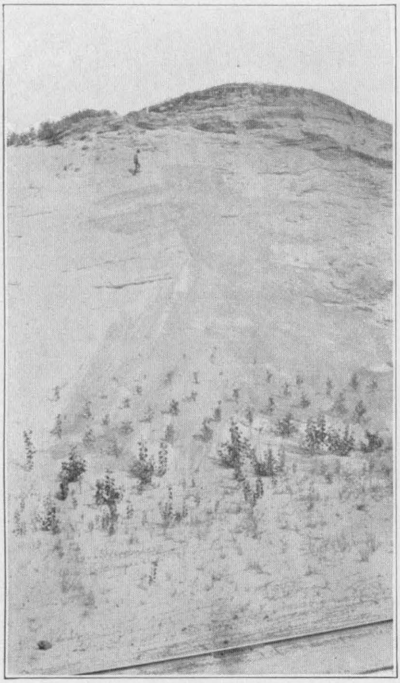
Lakes or ponds are sometimes found in some of the depressions between the dunes on the bluff. Several of them occur in the area south of the Wapsipinicon valley and one was seen on the Illinois side, near the crest of the bluff in Sec. 10, Garden Plain township. A small lake in the region of loess dunes in the E. ½ of Sec. 29, Princeton township, is shown in Pl. 18, B. Another occurs in the S. W. ¼ of Sec. 30 of the same township.

DUNE AREAS OF THE UPLAND BACK FROM THE BORDER OF THE BLUFFS.

A few scattered patches of dune topography, with sometimes a few hills of shifting sands, are found on the upland back from the bluffs. In the region covered by the Iowan drift-sheet in Iowa, such patches occur in the N. W. ¼ of Sec. 20, Camanche township, Clinton county, in Secs. 6, 5, and 8, southwest of Elvira, Center township, and at several places along the lower course of Brophy creek. On the Garden Plain upland a number of sandy ridges or successions of hills occur. East of the Cattail channel, on the region of even topography (p. 44), many dune-like ridges of fine sand and sandy loess are found, and the whole region has much sandy material. The upland patches of dune topography are elongate, and have their longer axes in a west-northwest to east-southeast direction. The material is fine sand or sandy loess.

DEVELOPMENT OF DUNE AREAS.

How Dunes Migrate.—The manner in which dunes advance is shown at many places in this region. The sand is seldom carried for any appreciable distance in one transit, but advances by a succession of short journeys, between which may occur longer or shorter periods of rest. The sand is shifted up the windward side of the dune, and dropped just beyond the crest. This process develops a gentle windward slope, *a b*, Fig. 26, and a steeper lee slope *b c* which may be as steep as the angle at



A. A dune in Whiteside county, Illinois. Fine sand extends more than 60 feet above the railway track in the foreground.

B. Detail of upper portion of A, showing cross bedded undulating layers of dune sand.

which sand will rest. This seldom exceeds 20°. With a shifting of the wind to the opposite direction, the profile *a b c*, Fig. 26, may be changed to *c b′ a*. If the winds from one direction prevail, a dune area may advance to the leeward, and encroach upon territory not formerly occupied by dunes. In several places beyond the bluff border area, this is now going one, or has recently taken place, and farming land is being slowly covered by the dunes.

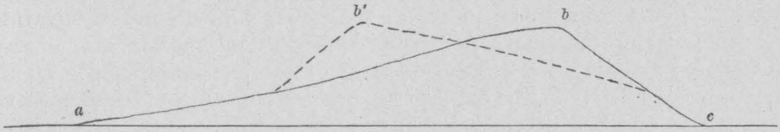


FIG. 26. Diagramatic sections of a dune showing the gentle windward side *a, b*, and the steep lee side *b, c*. With a reversal of the direction of the wind, the profile *a b c* would be changed to *c b′ a*.

Structure of Dunes.—Exposures showing the structure of the sand are exceptional because of the ease with which the material slumps; but at least one exposure deserves mention in this connection. It is a cut on a branch of the C., B. & Q. Ry., in Sec. 30 and 31 of Ustick township, at the head of the Cattail slough. Here the bluff is formed of sand deposits, and the railway running along the face of the bluff has made some deep cuts. A few hundred yards south of the point where the C., B. & Q. Ry. crosses the C. & N. W. Ry., an exposure of 50 to 60 feet of sand is made (Pl. 19, A.) The sand is fine grained, with indistinct wavy layers. Some of the layers are parallel with the slope of the hill side, while others dip in the opposite direction. A series of layers dipping in one direction may be cut off above by another series which rests upon the truncated edges of the first. In fact the features shown are just those to be expected in a sand dune area, in which the hills are building out in one direction today, and in another tomorrow, and in which the layers put down today may be partially eroded away tomorrow, and the material deposited on another slope at a different angle. Near the top, the sand passes into a sandy loess layer which is 2 to 10 feet thick (Pl. 19, B.), and at the highest part of the cut the loess is overlain by a more recent deposit of sand several feet thick. The sand is now being transported up the steep face of this bluff, and small dunes with gentle windward and steep lee slopes are encroaching upon the farm land beyond.

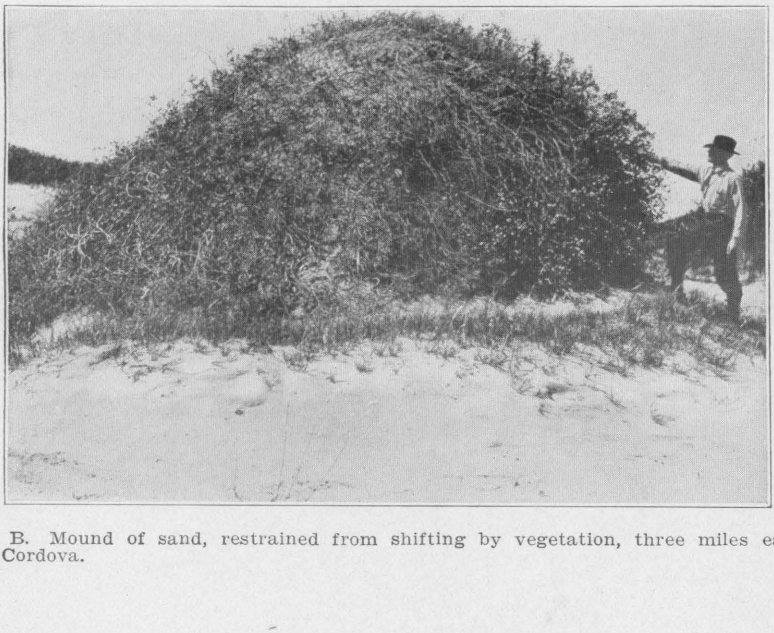
Plate 20, A, from this locality, shows a kind of surface markings often found on shifting sand. They are wind ripples, which consist of roughly parallel ridges and intervening troughs. They are formed transverse to the direction of the wind. The ridges are usually less than an inch in height, rising gently on the windward side, (to the right in the figure) and dropping off more steeply on the lee side. The difference in slope is due to the way in which the sand is carried; most of it is rolled along the surface up the gentle incline of the ripples, and dropped just beyond the crest. It then rolls down the front of the ripples forming the steep slope. In miniature, these ripples reproduce the form of a dune. The fine grains are blown on over to the next ripple or may be carried bodily for some distance. The coarse grains are rolled, and so the steep slope is made up of coarser grains.

Effect of Coarse Material.—The material of the valley flats, for some distance below the thin soil horizon, is fine sand with some layers of coarse sand and gravel. When this material is exposed, the finer part is shifted by the wind, and piled in hills and ridges. As it is shifted back and forth from place to place, the newly blown sand is separated from the coarser material, the latter being left on the surface, or even let down to a lower level by the removal of the enclosing sand. In this way, the upper parts of the sand hills come to contain only that material that may be handled by the wind, while the bottoms of the pits between the hills may show the residual gravels and pebbles. If the sand is shifted away from the region where it first lay, the pebbles left may accumulate until they form a complete covering over the surface. Then the wind cannot get at the fine material below, and wind erosion is impeded, or completely stopped. Illustrations of this feature were seen in a number of sand dune areas of the valley flats, and especially in the area at the northwest corner of the Garden Plain upland. Here, at the west edge of the area, in the W. ½, N. E. ¼ of Sec. 3, Garden Plain township, considerable patches occur over which the pebbles cover the surface, effectively preventing further erosion.

An Effect of Vegetation.—An illustration of the way in which vegetation may hold the sand and prevent shifting is shown in Pl. 20, B, which is from a dune area on the Cordova flats. Similar features are shown in Pls. 17, A and 17, B. There are apparently two processes by which these mounds may be developed. In one case, the vegetation starts as a little patch of some trailing shrub like that shown in the right foreground of Pl. 17, A. All the sand that falls into the vegetation is retained, for the network of stems holds it against the wind. The shrub continues to grow and the sand to accumulate, until a mound of the size of those shown in the figures is formed. The other process is one of the retention of the sand where it is covered by vegetation, while the surrounding sand, is carried away. As the mound is isolated, the vegetation extends down the sides and covers the slopes. In the second case cited, the mound is more likely to be undermined, for the stems do not so thoroughly permeate the mound as when it has been built up around them. Most of the mounds are probably the result of a combination of the two processes.

Relation of Bluff Border Dune Areas to the Lowlands.—As seen by an inspection of the maps, bluff border dune areas occur to the east and south of the great valleys, while to the north and west they are absent. The prominence of the bluff border dune area usually varies with the width of the valley to the west and northwest. These relations have a significance, and there can be no doubt that the material of the bluff dunes was obtained from the valley flats, and carried out upon the edge of the upland by the westerly winds. We have illustrations of this process now going on at various places in the region. At the northwest corner of the Garden Plain upland, for example, the sand dune area of

A. Sand ripples. Windward slope to the right.



B. Mound of sand, restrained from shifting by vegetation, three miles east of Cordova.

the valley flat passes by a gradual rise into the bluff border area (Pl. 17, B), and the sand is now being shifted up the slope and over the crest of the bluff, out on to the upland.

Direction of Dune Migration.—The upland dune areas are in regions of very sandy drift, and the material was gathered together from the immediate locality in which they occur. These areas have a general east-west direction, and are advancing to the east. The bluff border areas often have ridge-like extensions to the east or southeast, and in all the areas where sand is now shifting the general advance appears to be in the same direction. All these facts and many others show that the winds which are most important in the formation of the dunes, are the prevailing west and northwest winds.

In this connection it should be noted that the direction of the longer axes of the paha (p. 43), is identical with the direction of advance of the dune areas, and also that the paha consists largely of loess and fine sand which is often being shifted along to the east-southeast, and increasing the length of the paha ridges. From this it appears probable that the prevailing winds have aided in the development of the paha, and possibly the loess and sand of the paha-like ridges may have been deposited by the wind. Probably most of the paha have nuclei of glacial drift, coated with, and lengthened by eolian deposits.

Time of Formation.—The time immediately following the filling of the main valley during the Wisconsin glacial epoch, was probably the time of greatest dune development, for then vegetation had not become firmly fixed upon the new sand surface of the lowlands, and the soil was not present. As vegetation increased and a soil was developed, the wind became less effective. Dunes were also formed before the Wisconsin glacial epoch. Since the Wisconsin glacial epoch, dune formation has probably been constantly going on locally.

CHAPTER VII.

POST-GLACIAL CHANGES.

The chief effective process in this region since the glacial period has been erosion, although locally some deposition has taken place.

EROSION.

EROSION OF THE UPLANDS.

When an ice-sheet withdrew from the region, erosion began on the new drift surface which it left, and unless this same area was covered again by a later ice-sheet, this erosion has continued uninterrupted to the present time. The area of exposed Kansan drift has been eroded continuously since the Kansan glacial epoch, the exposed Illinoian drift since the Illinoian glacial epoch, and the Iowan drift since the Iowan epoch. The erosion of the unglaciated aera was not interrupted by the glacial period. All the upland of this region has suffered continuous erosion since the close of the Iowan glacial epoch. The erosion of post-glacial time cannot be separated from that which occurred during the inter-glacial epochs, but the larger part of the erosion which the Kansan and Illinoian drifts have suffered was accomplished before the close of the Iowan glacial epoch, for the surface had its present topography, essentially, when the loess was deposited.

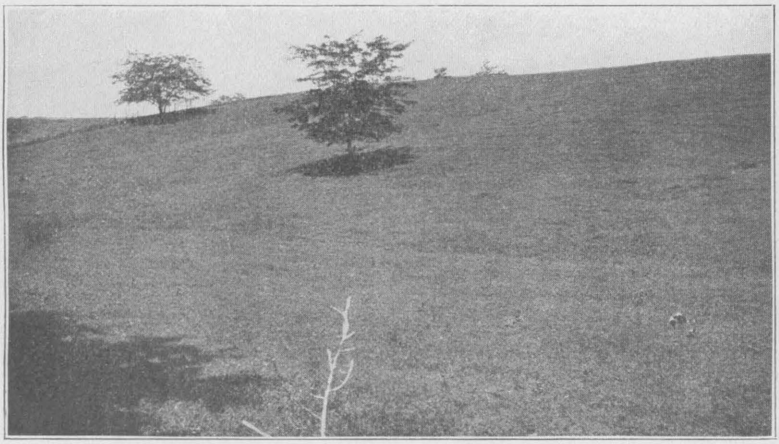
Erosion of the drift covered upland has made many new valleys and cleared out some old ones. If a pre-glacial valley was not completely filled by drift, it commonly became the course of a stream after the retreat of the ice, and such valleys were sometimes cleared of their drift. Many of the secondary valleys of this region, as those of Duck creek, Mill creek, Elk river, Plum river, etc., are wholly or in part of this class.

The removal of part of the filling deposited during the Wisconsin glacial epoch in the lower courses of some of the side valleys, left the remainder as terraces, as described on page 50.

CLEARING OUT OF THE GREAT VALLEYS.

In the discussion of drainage changes (Chap. V) the history of the great valleys was traced to the Wisconsin glacial epoch, when they were filled to the level of the second bottoms, and an alluvial plain extended from bluff to bluff.

A. Gullies, showing erosion on cultivated loess covered slopes.



B. A grass covered slope without gullies.

When the Wisconsin ice-sheet melted away from the head waters of the Mississippi and Rock rivers, these streams, no longer loaded with sand and gravel, began to cut into the plains which they had developed. At first these streams may have had many channels, that is they may have been braided rivers, but gradually those more favorably located became the main ones. Above Clinton, the most direct course of the Mississippi was along the Iowa bluff, and this course finally acquired all the drainage of the valley. This course passes to the west of the hill upon which Fulton is located. The course to the east of the Fulton island has been kept open however, and is yet followed by some of the flood waters. The strip of lowland bordering the Illinois bluff from Plum river south, through Idens and Dyson lakes, was followed for a considerable time, and was lowered 10 to 15 feet below the terrace to the west. Cattail channel must have been followed, at least by flood waters, for some time, for the level of the sand filling below the peat is very little above the present level of the Mississippi.

At the head of the Cordova flats just below Albany, the waters of the Mississippi may have been divided at the time of the maximum valley filling, part going down the Meredosia-Rock river course, and part by the way of the present Mississippi through the Narrows. These courses seem to have been quite evenly balanced; and possibly the Mississippi was divided between them until very recently, or it may have flowed alternately through the two. The course by the Narrows now carries all the water of the Mississippi. It is much shorter, and probably the narrowness of the channel aided the stream in clearing it out. The Meredosia course is very little higher than the level of the Mississippi, and until dams were placed across its ends, the flood waters of the Mississippi passed down it to Rock river, or if Rock river was the higher, its waters passed north through the Meredosia valley to the Mississippi at Albany. The Rock River valley is well cleared of glacial drift and has apparently held a much larger stream than the present river. Its bluffs are abrupt, and bear evidence of considerable post-glacial erosion. Both the Narrows and the Meredosia-Rock river courses lead over an alluvial filling in their upper part, and then over a rock bottom below Hillsdale and Leclaire. Pleasant Valley was lowered 14 to 20 feet below the elevation that it must have had at the time of maximum filling. It was then abandoned in favor of the present course south of the Moline upland.

The former drainage line southeast from Erie to the Illinois river was apparently not followed by post-glacial drainage, for its elevation has not been reduced below the terrace level. A few ill-defined shallow channels traverse the sandy region south of Erie, between Rock river and Green river, and probably represent the courses of the last drainage in this direction, just after the stage of maximum valley filling.

The portions of the valley flats that have been left at or near the level of maximum valley filling of the Wisconsin glacial epoch form the terrace or second bottoms. Those portions reduced to near the present river level from the flood-plains. These features have been described in an earlier part of the report (Chap. IV, pp. 46-48).

RAPID EROSION OF CULTIVATED LAND.

When the land is cultivated the covering of grasses is removed and the surface is subjected to rapid erosion. If the slopes are steep and covered with loess they often become so badly cut up by gullies (Pl. 21, A) that they cannot be cultivated, but must be seeded to grass again. This checks the erosion, and the gullied slope becomes less rugged. Slopes equally steep, but not cultivated, are less subject to the development of gullies (Pl. 21, B). The contrast is seen by comparing Pls. 21, A and B, which represent portions of the same slope about 50 yards apart.

The material derived from the rapid erosion of cultivated lands has often overloaded the streams and caused them to aggrade the bottoms of small valleys (Pl. 22, A). The effect of a recent rainstorm upon the valley bottom is shown in Pl. 22, B. These small flat bottom valleys are common throughout the region. The flats terminate abruptly against the slopes of the valleys, and are quite different from those developed by the lateral cutting of streams. When the field drained by one of these valleys is seeded to grass again, the flat may be cut into, and the valley deepened.

DEPOSITION.

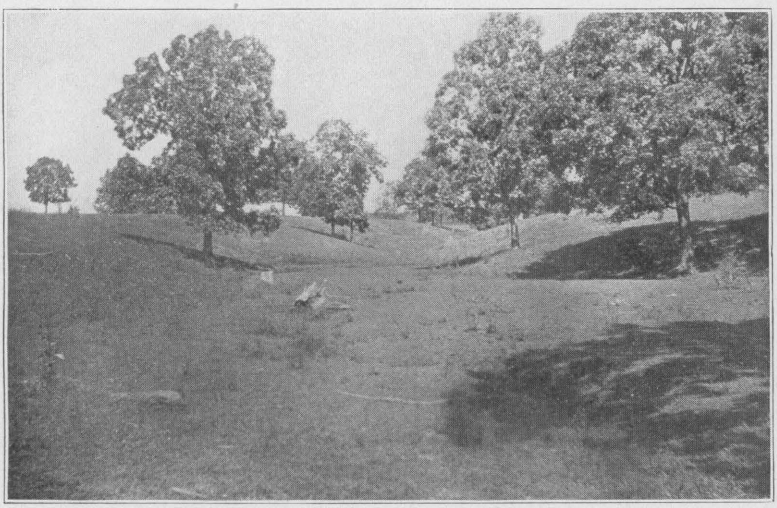
The deposits of post-glacial time consist of (1) alluvial material deposited by streams mostly on the present flood-plains, (2) the deposits laid down in lakes, ponds, marshes, etc., (3) a part of the loess, and (4) most of the wind blown sand. The loess and sand have been considered in Chap. VI.

BY STREAMS.

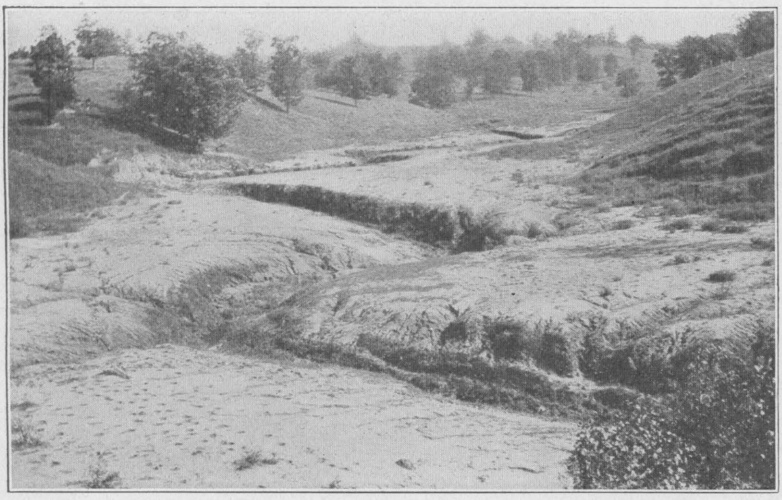
The stream deposits consist mainly of the alluvium which covers and underlies the flood-plains of the great valleys. Common thicknesses are 3 to 5 feet, but in some places there is as much as 15 feet. It consists of black mud, mixed with more or less sand. Flood-plain deposits occur also in many of the smaller valleys of the region.

Alluvial deposits are now being formed at the edge of the lowlands of the great valleys, especially where side valleys open out upon the flat. In the upper part of these side valleys, the gradient is relatively high, and the velocity of the stream allows it to carry a large load of sediment. When the water reaches the lower gradient of the valley near its mouth, and of the lowland plain of the main valley beyond, the velocity of the stream is decreased, and part of the load is deposited. The volume of the stream also may be decreased, especially in dry weather, by the sinking of part of the water into the sandy alluvial deposits. This still further decreases the carrying power of the stream and so favors deposition.

So long as the stream is held between valley walls, the bottom is built up more or less evenly and an aggraded plain is developed from bank to bank. At the mouth of the tributary valley, the stream may



A. Flat valley bottom aggraded by the wash from the cultivated fields above.



B. Valley bottom covered by silt deposited from flood waters.

escape laterally, and at successive stages it flows by various courses which diverge from each other like the rays of a fan. In this way a fan shaped alluvial deposit (alluvial fan) is formed, thickest at the point, and thinning radially toward its semicircular edge. A small alluvial fan or cone is shown in Pl. 23. The radial markings on the surface show the courses followed by the water at various times. Small alluvial fans like the one shown in this figure may have slopes as great as 10° to 15°; but the fans at the mouths of the side valleys commonly have very low slopes. Some of them extend out on the flat more than a quarter of a mile.

The following examples will illustrate the features of the alluvial fans at the mouths of the side valleys. About 5 miles north of Savanna in the S. E. 1/4 of Sec. 17, Washington township, a small creek comes down through the bluff from the northeast, and joins Rush creek on the flood-plain near the base of the bluff. In the lower course of this valley, considerable filling has recently taken place. The flood waters of the gully coming down from the steeper gradient to the east, and loaded with fine sand, drop their material when they reach the gentle gradient near the mouth of the gully. The valley floor is being built up by the deposits, and at the end of the gully a broad fan-shaped plain of fresh alluvial material extends out a short distance over the flood-plain of the Mississippi. A bridge on the bluff road, which crosses the stream near its mouth, is only about a foot above the surface. The approaches to the bridge are almost buried, and trees near by are buried up to their first branches. A ravine cutting the bluff near the south line of Sec. 29, Mt. Carroll township, Carroll county, has aggraded its floor in its lower course, and the stream has extended its sand plain 60 to 80 rods out on the Mississippi flat. Where the bluff road crosses the stream, a bridge has been buried, and a second bridge, built well above the first, is now only a few feet above the surface. The sand plain extending over the flat of the Mississippi has ruined many acres of valuable farm land, and is now extending into Dyson swamp. Similar examples are found at the mouths of several other ravines between this one and Johnson creek. and at various other places within the area. The conditions are especially favorable along the east bluffs of the Mississippi, for the ravines come down the upland through the bluff border dune areas, which furnish an abundant supply of fine sand.

IN LAKES, PONDS, MARSHES, ETC.

The deposits put down in ponds and marshes consist of sediment carried in by running water, and accumulations of vegetable matter which grow in the marshes or around the edge of the pond. The sediments are sand and silt of such nature as may be derived from the area drained.

The only considerable area of marsh and lake deposits on the upland of this region are on the Iowan drift of southern Clinton county. Here a few ponds and small areas of marsh land occur, in which some sedimentation has taken place and some vegetable matter has accumulated.

On the lowlands of the Mississippi and other large valleys, areas of deposition in swamps and marshes are more common. The long strip of marsh land extending along the Illinois bluff through York and Mt. Carroll townships, Carroll county, is receiving considerable sediment from the streams which flow into it from the east, and the east margin of the marsh is being gradually pushed back by this filling.

Many areas of the lowlands which were formerly swampy have been drained recently, and the sides of the ditches expose the underlying material. Such exposures occur in the Meredosia and Cattail sloughs, and on the lowland northwest of Erie. The material is a black mucky deposit and from this grades into a peaty material where the vegetable matter is most abundant.

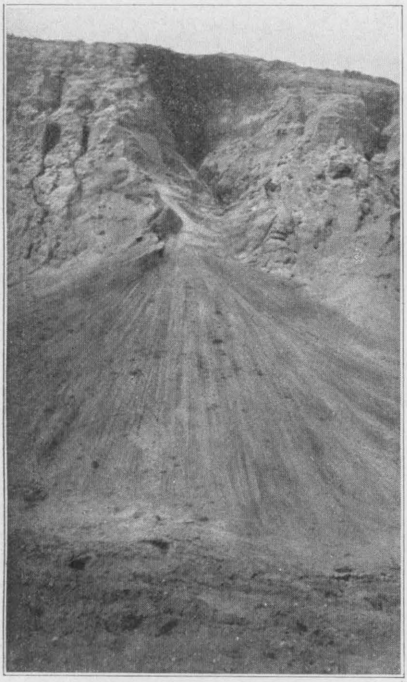
Peat in quantity underlies the Cattail slough (Pl. I). It is thickest on the divide between the creeks flowing to the north and to the south. Here, in the S. ½ of Sec. 29, Union Grove township, it attains a thickness of 25 to 30 feet. It thins in either direction and disappears before the ends of the valley are reached. In Sec. 7, 3 miles north of the divide the peat is about 12 feet thick.

Below the peat there is fine sand, the surface of which is almost level for the entire length of the channel, or perhaps has a slight slope to the south. Its elevation is about that of the flood waters in the Mississippi river (585 feet). When the flood waters of the Mississippi ceased to pass down the Cattail valley, this strip of lowland became a marsh and vegetable matter began to accumulate. The marsh conditions were best where the drainage was poorest, and where there was least erosion, and so the present deposit was built up, thickest on the low divide, and thinning in either direction.

The peat of the Cattail valley is a sphagnum moss peat, with a few stems of grasses. The moss is now growing in only a few places near the divide.

Some of the surface of the Cattail valley has been drained, and the peaty soil is very successfully used for truck gardening. In Sec. 7, Union Grove township, about 200 tons of peat are taken out annually to be used as one of the ingredients of a stock food, manufactured at Lyons, Iowa. The peat is not at present used as fuel, but at some future time, when other fuels are less abundant than now, the peat of Cattail slough may be valuable for this purpose.

Everywhere throughout the region more or less vegetable matter has been mixed with the soils, giving them their dark color. On slopes where erosion is rapid, very little humus accumulates and the surface material is usually yellowish clay. On the more even surfaces, dark colored soils usually extend to a depth of several feet. The nature of the soil depends upon the superficial deposit and the amount of humus material. On the lowlands where the superficial deposit is sand, a sandy black soil is usually present. On the upland back from the bluff the soil usually ranges from a yellow clay to a black loam but areas of sandy soil occur.



An alluvial fan at the sand pit of the C. & N. W. Ry. Co., near Elk River Junction. The radial markings on the surface show the courses followed by the water.

LIST OF PUBLICATIONS.

A portion of each edition of the Bulletins of the State Geological Survey is set aside for gratuitous distribution. To meet the wants of libraries and individuals not reached in this first distribution, 500 copies are in each case reserved for sale at cost, including postage. The reports may be obtained upon application to the State Geological Survey, Urbana, Illinois, and checks and money orders should be made payable to F. W. DeWolf, Urbana.

LIST OF PUBLICATIONS.

BULLETINS.

Bulletin 1. The Geological Map of Illinois, by Stuart Weller. Including a folded, colored geological map of the State on the scale of 12 miles to the inch, with descriptive text of 26 pages. (Out of print.)

Bulletin 2. The Petroleum Industry of Southeastern Illinois, by W. S. Blatchley. Preliminary report descriptive of condition up to May 10th, 1906. 109 pages. (Out of print.)

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AUTHOR.

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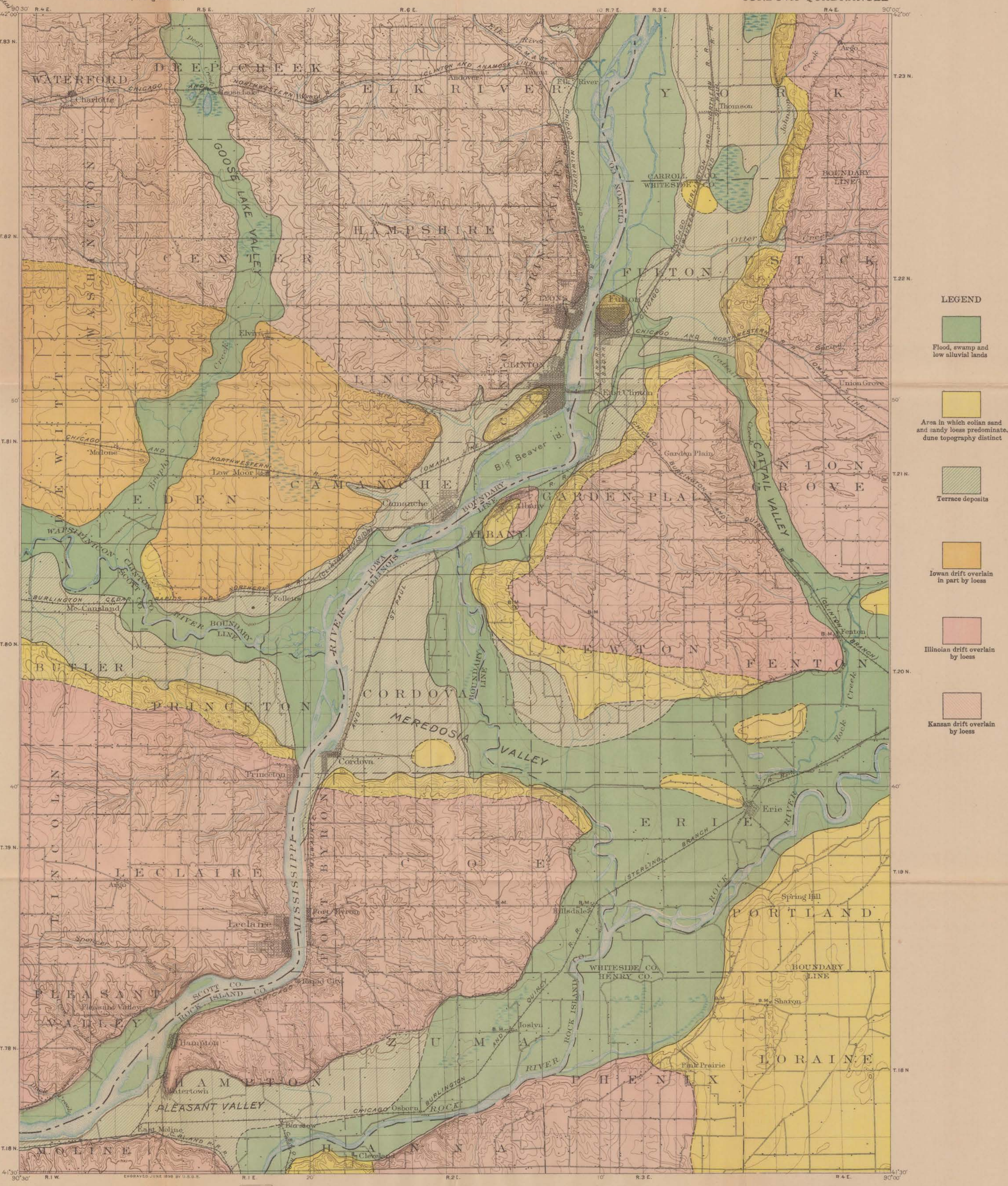
ILLINOIS STATE GEOLOGICAL SURVEY.
C. S. Deneen, E. J. James, T. C. Chamberlin, Commissioners.
F. W. DeWolf, Acting Director.

TOPOGRAPHY AND SURFICIAL GEOLOGY.

ILLINOIS-IOWA
CORDOVA QUADRANGLE



Topography by United States Geological Survey,
Jno. H. Renshawe, Topographer in charge.
Control by Geo. T. Hawkins and Miss. River Com.
Miss. River from Surveys by Miss. Riv. Com.
Topography by W. J. Peters, and R. C. McKinney.
Surveyed in 1890 and 1896.

Peters 1890
McKinney 1896

Scale $\frac{1}{125000}$

Contour interval 20 feet.
Datum is mean sea level.

Geology by J. Ernest Carman,
under the direction of
R. D. Salisbury.
Surveyed in cooperation with the
Iowa Geological Survey.

ILLINOIS STATE GEOLOGICAL SURVEY.
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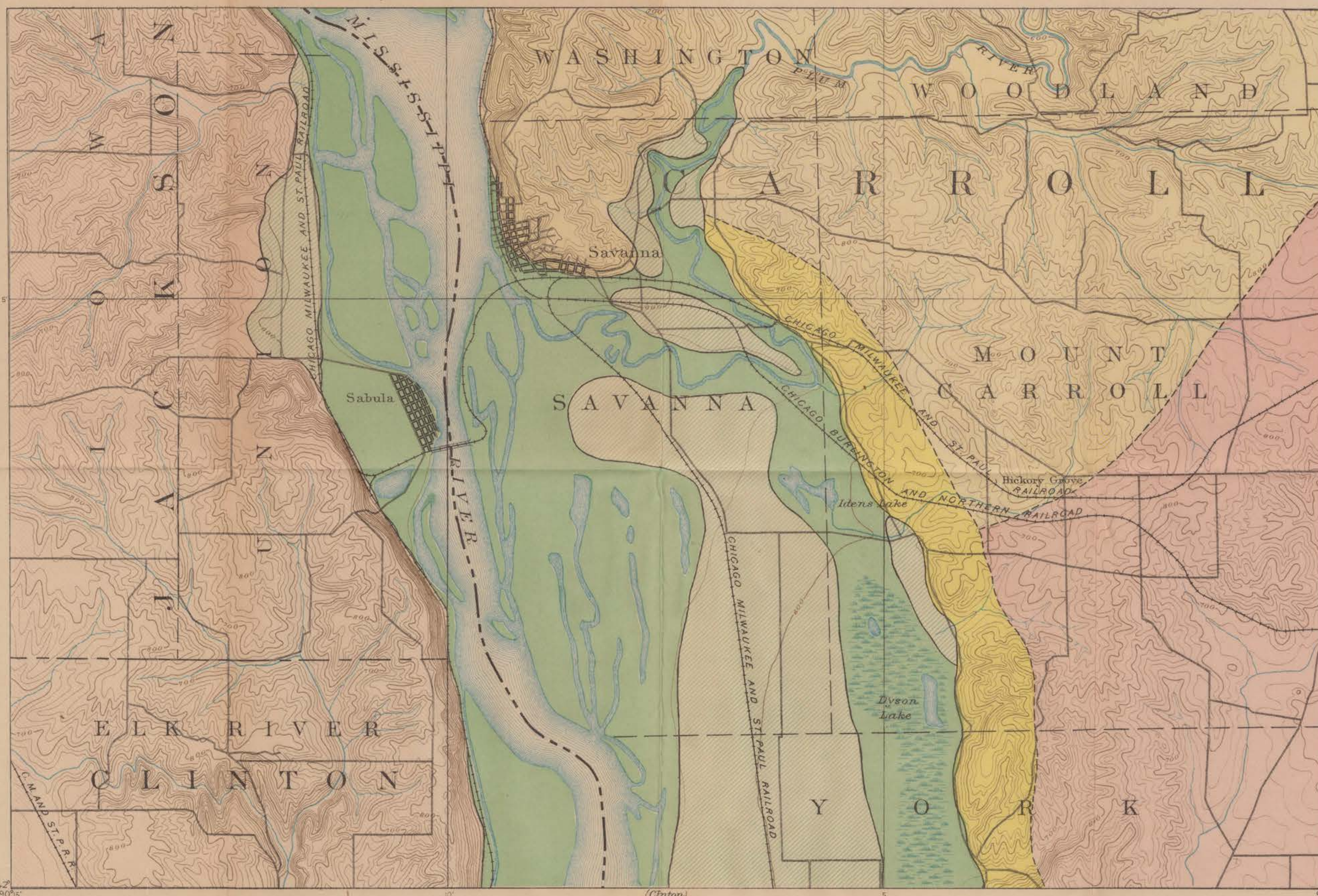
TOPOGRAPHY AND SURFICIAL GEOLOGY.

ILLINOIS-IOWA
SAVANNA SHEET



LEGEND

Flood, swamp and low alluvial lands

Area in which eolian sand and sandy loess predominate, dune topography distinct

Terrace deposits

Illinoian drift overlain by loess

Kansan drift overlain by loess

Driftless area

Topography by United States Geological Survey.
Henry Gannett, Chief Topographer.
John H. Renshawe, Geographer in charge.
Topography by W. J. Peters.
Surveyed in 1890.

Geology by J. Ernest Carman,
under the direction of
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